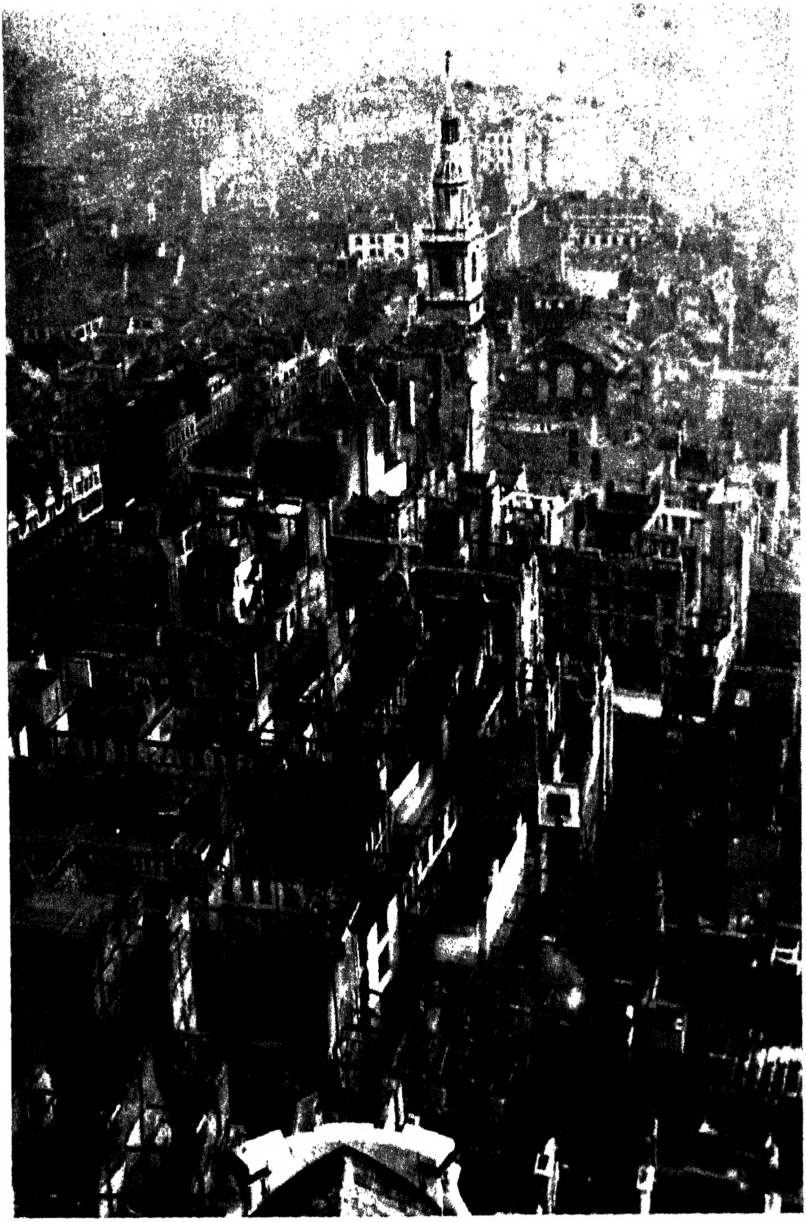
CIVIL DEFENCE



(Keystone)

View from St. Paul's Cathedral, London. Spring, 1941.

Frontispiece.

CIVIL DEFENCE

A PRACTICAL MANUAL PRESENTING WITH WORKING DRAWINGS THE METHODS REQUIRED FOR ADEQUATE PROTECTION AGAINST AERIAL ATTACK

BY

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THIRD EDITION

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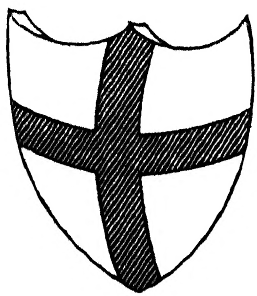

PREFACE TO THIRD EDITION

After eighteen months of the war the urgent demand for a Third Edition of this work was met by a reprint of the Second Edition with corrections and additions to the letterpress and the addition of another chapter on the war and its effects on Civil Defence.

It is gratifying to note that the acid test of actual war conditions has only served to confirm the soundness of the principles of the science outlined in the earlier editions.

There is, of course, an inevitable effect on costs of works and prices of equipment, but except where otherwise specifically stated in the text, an all round increase of $33\frac{1}{3}$ per cent. can be made to the cost figures given in the volume for the purpose of estimation of wartime costs.

Local conditions must, however, be taken into consideration in arriving at a close estimate of cost of civil defence works, but the calculations included in this work having been made on a uniform basis will serve as a reliable basis of comparison.

As far as the exigencies of war conditions will permit, endeavours have been made to display the effects of test results on design for passive air defence.

C. W. G.

London,
March, 1941.

PREFACE TO SECOND EDITION

GREETED as " the first text book on the subject " the first edition enjoyed an encouraging press and quickly became out of print.

The evolution of the science and art of Civil Defence and the rapid march of events in 1939 confronted the publishers with an insistent demand for a revised and enlarged edition which was at once put in hand.

The latter part of this work was completed under the trying conditions following the outbreak of the second Great War, but by a merciful dispensation of providence this country was spared the full force of an aerial attack at the outset and belated schemes for Civil Defence were thus enabled to proceed unhindered, albeit with feverish activity.

War conditions have had their inevitable effect upon costs, but the respective prices given in the present volume may be confidently accepted as giving a reliable comparison and are, of course, not binding upon manufacturers or contractors.

C. W. G.

LONDON,
November, 1939.

PREFACE TO FIRST EDITION

THE ineradicable instinct of self-preservation in man prompts him to clutch at any straw in a vital emergency.

Experience in war has shown that even the resourceful serving soldier all too often exhibits peculiar ideas of what constitutes adequate protection and shelters constructed without the exercise of the fundamental principles of structural stability have proved themselves to be the greater danger.

Yet the mere act of occupying them has contributed in no small measure to the maintenance of mental equilibrium in the stress of many a bombardment.

In the presentation of this volume, attempts have been made to analyse the problems confronting modern society for the adequate protection of the civil population, and it is confidently hoped that its appearance will not be taken as an acceptance of the inevitability of war, but rather as a means of focussing national attention to the moral necessity for the prompt preparation of civil defence.

The author feels it incumbent upon himself to make his position quite clear at the outset.

He has considerable sympathy with the sentiments of the idealist but is forced by consideration of the facts of the present position to abandon utopian ideas and come out in the open definitely a realist.

He is not an alarmist nor an ultra-pacifist and has endeavoured to present and examine the facts fairly and without political bias in the fervent hope that Civilian Defence in all its aspects will be taken up seriously by the nation. The civilian population trained to protect itself will be largely insured against injury and panic and thus the great cities of this country—at present almost an invitation to the air raider—will not present tactical advantages worth the military effort and risk in securing them.

The appalling increase in the offensive power and suddenness of aerial attack makes even the hasty improvisation of defence

measures abortive and no apology is therefore offered for the earnest appeal for prompt and immediate preparation detailed in the present work.

The prices quoted in this volume are given for the convenience of the reader, and whilst every precaution is taken to ensure their accuracy this is in no way guaranteed. All prices are subject to verification when the specific requirements are known.

The names of manufacturers are given, but comparisons are not made nor intended, neither is the list claimed to be comprehensive. What have been described are intended as typical of the respective classes of shelter or equipment.

General acknowledgment is made in the references to the many sources to which the author is indebted for much of his material.

The author's thanks are also due to authorities and companies enumerated for permission to make use of information supplied in the preparation of illustrations, and in many cases for the loan of half-tone blocks.

The author also wishes gratefully to acknowledge his indebtedness to officials of the Home Office for much valuable help and criticism in the preparation of the work.

Views expressed are solely those of the author and are in no sense official.

Chapters are addressed to the layman as well as the architect and builder, and it is hoped that the details, working drawings and suggestions herein contained will assist forward the humanitarian work of the protection of the defenceless citizen.

C. W. G.

July 7th, 1938.

ACKNOWLEDGMENTS

THE author wishes to record his grateful thanks to the under-mentioned authorities and companies for information upon which illustrations have been based and in many cases for the loan of blocks.

The War Office, The Home Office, His Majesty's Stationery Office, The Institution of Civil Engineers, The Air Raid Protection Institute, The Am. Inst. of Heating and Ventilating Engineers, The Cement and Concrete Association, The Timber Development Association, *The Illustrated London News*, *The Builder*, *The Architect and Building News*, *The Photographic Journal*, *The R.E. Journal*, Messrs. C. F. Anderson & Son Ltd., Bells United Asbestos Co. Ltd., Bracey & Clark Ltd., The Carrier Engineering Co., Concrete Ltd., Conjoint Constructors Ltd., The Chatwood Safe Co., The Chloride Electrical Storage Co., Richard Costain Ltd., The Crittall Manufacturing Co. Ltd., Durasteel Roofs Ltd., The Gas Proofing Co. Ltd., Messrs. Greenwoods Ventilating Co. Ltd., Messrs. Hobbs, Hart & Co. Ltd., Messrs. Henry Hope & Sons Ltd., Messrs. Jenson & Nicholson Ltd., Messrs. Keith Blackman & Co. Ltd., Messrs. George Kent Ltd., Messrs. Kontragas Ltd., Messrs. John Laing & Co. Ltd., Mills Scaffolding Co. Ltd., Murex Welding Processes Ltd., Messrs. Platt Bros. Ltd., Messrs. Nissen Buildings Ltd., Messrs. Norcon Ltd., Messrs. Rigby (London) Ltd., Roycott Protectors Ltd., Messrs. Siebe, Gorman & Co. Ltd., Siegwart Fireproof Floor Co. Ltd., The Silicate Paint Co. Ltd., The Solent Engineering Co. Ltd., Stewarts & Lloyds Ltd., The Sturtevant Engineering Co. Ltd., Universal Air Defence Services, Universal Floors Ltd., Messrs. Wallach Bros. Ltd., Joseph Westwood & Co. Ltd., R. White & Sons, Williams & Williams Ltd., Wolverhampton Corrugated Iron Co. Ltd., John Yuille (Metal Work) Ltd.

The author gratefully acknowledges the permission of the Controller of His Majesty's Stationery Office to reproduce illustrations from Home Office publications Air Raid Precautions Memorandum No. 10—"Provision of Air Raid Shelters in Basements," and "Directions for the Erection and Sinking of the Galvanised Corrugated Steel Shelter"; and of other illustrations appearing in Statutory Rule and Order, 1939, No. 920 "Air Raid Shelters for Persons Working in Factories, Mines and Commercial Buildings." These illustrations have the following figure numbers in this volume: 101, 102, 103, 106, 107, 149, 150, 151, 152, 153, 154, 187, 188, 189, 190, 195, 196, 243.

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INTRODUCTION

The passive defence of the civil population of Great Britain against aerial attack is a prodigious undertaking, and the far-seeing air raid precaution schemes of the Home Office, supported to the fullest possible extent by Local Authorities, cannot secure more than a modicum of success without the whole-hearted co-operation of the citizen himself. That the efforts to the prompt establishment of efficient protection must be properly co-ordinated is self-evident, and the reader is therefore urged to consult the official publications issued under the authority of the Secretary of State by the Air Raid Precautions Department of the Home Office, with the assistance of other Government Departments concerned.

A list of these documents is given in the bibliography at the end of this volume, and the reference numbers given in the text refer thereto.

The use of poison gas in war is forbidden by the Geneva Gas Protocol of 1925, to which this country and all the most important countries of western Europe are parties, and the Government in their official publications state that they would use every endeavour on an outbreak of war to secure an undertaking from an enemy not to use poison gas. Nevertheless, the risk of poison gas being used remains a possibility and cannot be disregarded.

The Air Warfare Rules formulated at The Hague in 1923 state that aerial bombardment is legitimate only when directed at military objectives, the destruction of which would constitute a military advantage, and that aerial bombardment for the purpose of terrorising or injuring non-combatants or destroying private property is prohibited.

Further, at the World Conference on Disarmament, 1932–33, the principle of the abolition of bombing non-combatants was accepted.

Recent events on the Continent and in the Far East have unfortunately demonstrated the fact that to place too much reliance upon the observance of these humanitarian principles is not justified, and that passive defence of the civilian is now a vital necessity.

For the convenience of the reader a short glossary of technical terms used in this volume is given below :—

An AIRCRAFT BOMB is a container holding high explosive (H.E.) or incendiary mixture or gas, with means of detonating, burning, or discharging the filling. The container is often referred to as the CASE.

AIR LOCK.—A compartment or lobby at the entrance to a gas-protected room or shelter which enables persons to pass in and out without admitting gas.

The ANGLE OF IMPACT is the angle which the bomb makes with the vertical at the moment of impact.

ANTI-DIM OUTFIT.—The materials provided for treating glass eye pieces of respirators so as to prevent dimming by moisture.

BATTER.—The slope of the face of any earthen, stone or masonry structure which is not vertical.

BLAST means the pressure created by explosion in the air which surrounds the explosion itself.

BLEACHING POWDER.—Chloride of lime, calcium hypochlorite—a white powder made by treating slaked lime with chlorine.

Not very stable, it readily gives up chlorine when exposed to air or water. Should be kept dry in airtight containers.

Much used for decontamination of mustard gas, with which it forms a non-vesicant compound

Unadulterated it acts violently with the mustard gas, producing heat, causing flame and driving off mustard gas vapour.

Therefore used with sand or fine earth, 1 part of bleach to 3 parts diluent.

BORROW-PIT.—An excavation from which earth is taken for a particular purpose, *e.g.*, building a breastwork.

BREASTWORK.—A defence work of which the greater portion of its height is above ground level.

BRISANCE is shattering power proportional to volume of gas per gram × calories per gram × velocity of detonation × density.

BUTT.—The thick end of a spar.

The service CEILING of bombers is the height at which the rate of climb has fallen to a certain defined limit (*e.g.*, 100 ft. per minute—about 30,000 ft.), but 15,000 ft. is the probable maximum height which laden bombers would ordinarily attain.

CONCENTRATION refers to the quantity of chemical vapour present in a given volume of air.

(*a*) grams per cubic metre.
=(*b*) milligrams per litre.
=(*c*) ounces per thousand cub. ft. (approx.)
—all ratios of weight of gas per volume of air.

Parts per million is a purely volumetric ratio.

$$\text{Parts per million} = \frac{T}{0{\cdot}0000161\ M.P.}\ \text{mg. per litre,}$$

where T is the absolute temperature in degrees Centigrade.
M is the molecular weight of the gas,
and P is the barometric pressure in mm. of mercury.

An irritating concentration is one which produces an irritant effect without impairing a man's efficiency, and the lowest irritant concentration is often called *threshold concentration.*

An *intolerable concentration* is one in which a man cannot exist for any appreciable length of time without impairment of functions.

In the case of lacrimators it is the maximum concentration a man can tolerate without masking.

A *lethal concentration* is one which sooner or later causes death. The numerical value is higher for the shorter periods of exposure.

CONTAINER.—The part of the respirator containing the filter and the gas absorbent.

CONTAMINATION.—The liquid or vapour remaining on an object or person as a result of exposure to gas (usually a persistent gas).

DECONTAMINATION.—A process intended to remove the contaminating gas or to render it harmless.

DETONATION.—A low explosive burns by a process of rapid combustion, but a high explosive functions in a far more rapid manner known as detonation.

DOG.—A bar of iron of which the ends are pointed and bent inwards at right angles, used for fastening heavy timbers together.

DUG-OUT.—An underground chamber or [illegible]

An EXPLOSIVE is a substance which, on application of a suitable stimulus to a small portion of the mass, is converted in a very short interval of time into other more stable substances, largely or entirely gaseous. Explosives are termed low or high according to the way in which this conversion to the gaseous state occurs. Low explosives "shift," but high explosives "shatter."

The EXPLOSIVE FACTOR is expressed in terms of the number of times the power of an explosive exceeds that of service black gunpowder when used in a mine.

FACE-PIECE.—The part of a respirator which covers the face.

FRAGMENTATION is the distribution of fragments or splinters from a bomb which takes place in all directions when the bomb detonates on the surface in the open.

A FUZE is a means of detonating the filling of a bomb. It may be instantaneous or may have action delayed to any desired amount.

GAS.—Includes any chemical substance, solid, liquid or gas, used in war for its poisonous or irritant effects on the human body.

There are three distinct groups of these agents:—

(*a*) *Gases* which are chemical agents which have physiological effects calculated to incapacitate military personnel.

A gas which produces death is called a *lethal* agent and others which under field conditions cause minor injuries are irritants.

(*b*) *Smokes* which are used for screening purposes. They may be toxic, burn or corrode, but primarily they are used in concealment.

(*c*) *Incendiaries*, which are used to start destructive fires.

Gradient.—A slope represented by a fraction, *e.g.*, 1/30 represents a rise or fall of 1 unit measured vertically for every 30 units measured horizontally.

Groundsill.—The bottom member of a frame or sett used in work underground.

Hydrolysis is the reaction of any chemical substance with water and if the resulting compound is poisonous decontamination by hydrolysis alone is not possible.

Injurants are gases which are highly toxic and are usually lethal in their effect.

Irritants are temporary in their effect and are not lethal. They attack the eyes, nose and chest, and are sometimes called *sneeze gases* or *sternutators*.

Lacrimators cause intense temporary irritation to the eyes and produce a profusion of tears.

Lung Injurants attack and injure the bronchial tubes and the lungs.

Non-persistent Gas.—A gas which forms a cloud (not necessarily visible) immediately it is released and leaves no liquid contamination on the ground.

Overhead Cover.—Protection by means of a roof, against splinters, shells or bombs.

Paralysants are systemic toxics which exert a direct paralysing effect upon the heart and nervous system ; they are usually the most deadly.

When a bomb passes through a target it is said to perforate it, and Penetration is used to mean entry into a target short of Perforation. The minimum perforating velocity is defined as that velocity which just allows the bomb to perforate.

Persistency of a Gas measures the length of time the gas remains in sufficient concentration to necessitate protection against its effects.

The persistency of a combat chemical agent is inversely proportional to its rapidity of volatilisation.

PERSISTENT GAS.—A gas in liquid form which evaporates slowly and so continues to give off dangerous vapour for a long period.

The COEFFICIENT OF POTENTIAL ENERGY is the product-volume of gas per gram (reduced to normal temperature and pressure) × calories per gram.

RESPIRATOR.—An apparatus designed to protect the eyes and lungs from gas.

SENSITIVITY.—The ease with which a person is affected by gas.

SPITLOCK.—To mark out a line on the ground with the point of a pick-axe.

SPOIL.—The material resulting from any excavations.

Equivalent STATIC PRESSURE means that pressure which, if maintained steadily upon the structure, would produce the same maximum stress as that produced by the blast wave itself.

The STRIKING VELOCITY is the velocity of a bomb at the moment of impact.

TEMPLATE.—A pattern, guide or model used to indicate the shape any piece of work is to assume when finished, *e.g.*, wood laths nailed together to outline the section of a trench used to check the accuracy of the work.

TOPSILL.—The top member of a frame, sett or case used in work underground.

A TOXIC.—Any substance which applied to the human or animal organism—internally or externally—is capable of causing death or serious interference in normal organic functions.

TOXICITY is the measure of the toxic effect of a poisonous agent, and is the measure of its concentration times the period of exposure to its effects.

The flight path or TRAJECTORY of a bomb is a curve which would be a parabola *in vacuo*, but in air is somewhat steeper.

TRAVERSE.—A buttress of earth provided between two adjacent portions of a trench for protection against, and to localise the effect of, bursts of bombs.

VESICANTS are agents which exert a blistering effect on the skin.

VOLATILITY refers to the capacity of a liquid to vaporise in the open air and is the amount held as a vapour in a unit volume of air at a given temperature and pressure.

It increases with temperature, and if the volatility of a toxic agent is greater than its lethal concentration for a ten-minute exposure, it is possible to set up killing concentration under field conditions.

CHAPTER I

PROBABLE FORMS OF AERIAL ATTACK

AERIAL attack may be aimed at—

A. Naval, Military, Air Forces and establishments;

B. Industrial centres, systems of supply and distribution;

or C. The civil population.

The improvements effected in active defence measures ensure that enemy aircraft will be kept at a height that makes accurate bombing less possible, and intended attacks under A or B may in effect result in indiscriminate bombing of the centres of population.

Enemy policy, in all probability, will be adjusted to comply with known defensive plans, and our assumptions, based upon the character and direction which air attack may take, must be liable to constant revisions as the state of our defences may develop. If ultimately our civil defence measures include the more widely extended provision of heavy protection, there would be a danger of creating a shelter mentality and a frequent interruption of processes of essential production. In these circumstances, also, feint aerial attacks by an enemy would be likely to be made with the object of immobilising the population.

It is thus not possible to predict the *exact* form which aerial attack in the future would take, but there is no doubt that the element of surprise and the demoralising effect of the swift use of overwhelming force would be tactical advantages which would be seized by an enemy.

A study of the statistical summary of raids on the administrative County of London during the Great War indicates the tactics then adopted.[65] (See Table I, p. 12.)

The attempts to "set fire to London" from the air persistently carried out in the raids during 1915–17 failed, largely because of the low efficiency of the incendiary bombs then used,

the bad marksmanship of the bomber and the brilliantly effective fire fighting services employed by the London Fire Brigade. Out of 354 incendiary bombs on London only eight caused fatal casualties and seven other injuries.

The maximum number of incendiary bombs which fell in London during one raid was 258 and these were distributed over a wide area averaging seven bombs per square mile.

There is no reason why a ruthless and untiring enemy zone bombing from a great altitude should not be able to increase this concentration a hundredfold, using incendiary bombs each many times more effective.

The increased use of high explosive bombs brought about a corresponding increase in casualties and material damage—an effect also observed in Paris. Out of 567 explosive bombs on London, 144 caused fatal casualties and 74 other injuries.

The total number of casualties in England from aerial attack during the Great War were 1,414 killed and 3,416 wounded; material damage £3,000,000, produced by 643 aircraft, which dropped in all 8,776 bombs weighing about 270 tons in the aggregate. About two-thirds was concentrated upon London.

In Germany the number killed by allied air raids is said to have been 2,500 and the material damage one and a quarter millions sterling.

The above results were accumulated after four years of warfare, but to-day an attacking force could drop as many tons of bombs on a single zone in one hour.

Modern aircraft are not only superior in speed, carrying capacity and radius of action but they are equipped with highly developed navigation and flying instruments enabling pilots to fly through cloud and darkness unerringly to their target.

Improved bomb releasing apparatus and sighting and calculating arrangements make the bombing of a selected target in conditions of good visibility a comparative certainty.

One successful raid by modern bombers on an undefended capital city could paralyse essential national services.

Gas, water and electricity undertakings could be put out of action; docks, bridges and railway stations bombed to destruction, transport services, food supplies and fuel stores cut off and Government offices disorganised.

A bombing squadron could leave a continental base and be

over the metropolis within twenty minutes simultaneously with the declaration of war if not before !

To-day bombing machines would approach at a speed exceeding 250 miles per hour and demolition bombs weigh up to 5,000 lbs. apiece. Such is the destructive power of these bombs that few, well placed, would be [illegible] to destroy administrative London !

Recent air manœuvres over London have demonstrated the fact that approximately 50 per cent. of an attacking aerial force would reach their objective in spite of active resistance by anti-aircraft and fighting airplane forces. Fast modern bombing units breaking through in daylight can be relied upon to demolish a target deliberately selected.

The horrors of chemical warfare involving the indiscriminate wholesale use of lethal and bacteriological weapons against concentrated civil populations of all ages and both sexes, with its aftermath of mass sickness and agonising death, will not be lightly resorted to for fear of reprisals.

Nevertheless aerial attack may take the form of bombardment with high explosive bombs, incendiary bombs, or gas bombs, and gas may be released from aircraft in the form of liquid spray or smoke. The heavier type of high explosive bomb will normally be reserved for military objectives but all types of attack may be employed simultaneously or in succession. Contamination of water and food supplies may also be attempted as well as the dislocation of essential services.

The dropping of explosive bombs would destroy property and incendiary bombs would then start innumerable fires. The subsequent use of gas would produce the greatest demoralisation of any population not highly trained and disciplined to resourceful self help and courageous fortitude.

There is no doubt that the scale of attack would be greatly in excess of anything experienced in the last war and the fullest possible use of favourable weather conditions would be made by an enemy.

In a high wind the gas cloud will be rapidly broken up, though gas may be forced into unexpected places by the wind pressure while the concentration is still high.

If there should be no wind at all, or only a slight drift, the worst situation will arise, though the effects will be more local.

FIG. 1.—Balloon Barrages for Aerial Protection of Cities.

In London this new arm of defence is under the control of the Auxiliary Air Force and 44 balloon barrage squadrons have been formed.

To face page 1

A dense cloud of gas will form at the point of burst and will remain in that particular area until it is gradually dispersed. It will find its way by diffusion and ventilation currents into areas, cellars, tunnels, etc., and once there it is not so readily cleared as the gas in the open streets. Once the gas has penetrated into a confined space it is not subject to the influence of the wind and air currents prevailing outside, and may continue to be dangerous when the outside air has become clear of gas.

Probably the greatest risk is from the use of a persistent gas, such as mustard gas, in conjunction with high explosive bombs. Material damage will be produced by the high explosive; and the mustard gas, whether used as spray or in bombs, will render the task of rescuing and treating casualties more difficult and hazardous.

The aim of aerial attack is to try to create such a state of panic among the civil population as to induce them to compel their government to sue for peace.

That panic can be avoided if every man and woman knows what to do in case of attack from the air, and preparations for defence are made *now*.

Piecemeal spasmodic efforts in a task of such dimensions are bound to be ineffective; and the avoidance of promiscuous large scale national expenditure on protective construction can only be attained by close co-operation between Government, Local Authorities and the Building Industry.

In England during the Great War there were twelve deaths per ton of bombs dropped, but recently in Barcelona these increased to thirty-two.[118]

With a reasonable degree of protection for the civilians, about twenty deaths per ton might be expected to-day.

"It has been ascertained that in recent air raids in Spain and China 98 per cent. of the casualties resulted from bomb splinters, bricks, tiles and *dèbris* scattered from buildings which had been hit, while only 2 per cent. were accounted for by direct hits."—*Financial Times*, July 27th, 1938.

In his Presidential Address before the A.R.P. Institute on March 14th, 1939, Mr. Oliver Simmonds, M.A., F.R.Aë.S., M.I.Aë.E., M.P., showed that in the absence of large-scale evacuation and efficient shelters we may take the casualties

TABLE I

STATISTICAL SUMMARY OF RAIDS ON THE ADMINISTRATIVE COUNTY OF LONDON DURING THE GREAT WAR.

Date.	Time.	Weather.	Raiders.	[illegible] Incendiary	[illegible] Explosive	Killed.	Injured.	Fires.	Damage.
31/5/15	Night	Fine warm	1 Zep. L.Z. 38	87	23	7	34	41	£18,596
17/8/15	..	Clear	.. L. 10	40	20	10	48	41	[illegible]
7/9/15	..	Mist	Zep. L.Z. 74 / Ship SL. 2	47	19	18	38	8	7,809
8/9/15	..	Clear	Zep. L. 13	15	13	22	87	19	530,787
13/10/15	..	Clear, slight N wind	Zep. L. 13 / .. L. 15	19	24	38	87	11	50,450
24/8/16	..	Rain	Zep. L. 31	8	36	9	40	6	130,000
23/9/16	..	Misty	Zep. L. 31 / .. L. 33	46	47	26	71	10	64,662
28/11/16	Day	Sunny	1 aeroplane	—	5	[illegible]	[illegible]		510
13/6/17	..	..	14 Gothas	—	92	142	390	5	125,953
7/7/17	..	..	21 ..	—	62	53	184	7	201,841
4/9/17	Night	Cloudy	9 ..	—	40	14	48	—	38,548
24/9/17	..	Clear	3 ..	16	13	14	49	2	15,002
25/9/17	..	..	3 ..	19	7	6	22	1	16,101
29/9/17	..	..	4 ..	—	23	13	80	—	21,873
30/9/17	..	..	5 ..	2	14	1	19	1	7,000
1/10/17	..	..	5 ..	—	28	11	41	1	44,004
19/10/17	..	Fog	Zep. L. 45	—	3	33	49	1	48,205
1/11/17	..	Drizzle	3 Gothas	17	21	0	3	4	7,443
6/12/17	..	Just before daybreak, clear	6 ..	238	9	3	15	52	92,477
18/12/17	..	[illegible]	[illegible] ..	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
28/1/18	..	Misty	4 Gothas, 1 Giant		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
16/2/18	..	[illegible]	1 Giant		[illegible]	[illegible]			[illegible]
17/2/18	..	..	1 ..		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7/3/18	..	[illegible]	3 Giants		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
19/5/18	..	Fog	13 Gothas and Giants		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
			25 Raids	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

2.—A unit of a Territorial land battery armed with 3·7 in. calibre anti-aircra capable of firing 12 rounds a minute to a height of 6 miles (32,000 ft.). Left, the pre the range finder; right, the gun. The two Territorial A.A. divisions will control 3,000 searchlights.

-pounder A.A. pom-poms capable of firing 100 rounds a minute will also be used aga aircraft

per ton in urban areas of average population (thirty to the acre) as likely to be in round figures: killed, ten per ton, and wounded, twenty per ton of bombs dropped.

There is strong evidence, corroborated from a number of sources, that we may expect during the first few weeks of a major war to have 3,000 tons of bombs despatched to this country per day.

Thus in a future war, unless civil defence be properly organised on a national and individual basis, we may expect casualties exceeding a quarter of a million per week! Happily, the statistics of the recent raids on Barcelona and Tarragona show that as shelters became widely available the casualties were reduced as follows:—

	Persons killed per ton.	Persons wounded per ton.
March, 1938 . .	6	12
May, 1938 . .	3	6
June, 1938 . .	1	2

The cost of providing adequate protection per head of the population need not exceed, on the average, £6 less than the cost of a funeral! (certainly not a prohibitive figure).

TABLE II

A.R.P. HAZARDS AND DEGREES OF PROTECTION PROGRESSIVELY OBTAINED MOST CONVENIENTLY BY THE PRECAUTIONS ENUMERATED.

	Approximate cost of protection per person accommodated at "normal" capacity.	Hazard.	Category No. 1 Refuges in buildings.	2 Refuges in buildings.	3 Covered trenches in open.	4 Covered trenches in open.	5 Covered trenches in open.	6 Strongholds A.	7 Strongholds B.	8 Strongholds C.
(a)		Machine gun .								
(b)		Gas spray .								
(c)	10s. to £1	Gas bomb .								
(d)	£1 to £1 10s.	Fire bomb . .								
(e)	10s. to £1	Splinters and fragments .								
(f)	£1 to £1 10s.	Blast from H.E. . . .								
(g)	£2 to £5	Demolition of buildings . . .								
(h)	£10 to £15	Direct hit ¼ ton H.E. bomb								
(i)	£15 to £20	" " ½ " " "								
(k)	£30 to £50	" " 1 " " "								

It will be understood that the above estimates can [illegible] circumstances may have a dominating influence upon costs and the [illegible] taken as a general guide.

and co-ordinated effort on the part of all concerned to provide shelter accommodation appropriate to the locality will do much to render indecisive the forms of aerial attack to be anticipated.

The air raid risks to a civil population in ascending order of severity can be summarised as in Table II.

Hazards

(a) Machine-gun from Low-flying Aircraft

A remote contingency effective only on personnel in the open or on congested road traffic. Taking cover in basements of buildings or covered shelters in the open affords complete protection.

(b) Gas Spray from Aircraft

Released from a safe flying height liquid gas spray would soon vaporise and be dissipated into an innocuous concentration.

The drop formation of the persistent gases like mustard and Lewisite can be maintained only when released a few hundred feet from the ground. Such a dangerous flight would only be undertaken when the target is considered of sufficient importance, and then probably after an attack by high explosive.

Shelter in gasproof refuges affords protection and decontamination adequate subsequent precaution. The hazard is, however, considered to be a remote one.

(c) Gas Bomb Attack

Now that civilian respirators have been issued and precautions to be taken against gas are more generally known, the risk from this hazard is minimised. The problem is dealt with in Chapter III, in which measures for almost complete protection are explained.

(d) Fire Bomb Attack

This is a much graver danger owing to the vast improvement in the design and effectiveness of the modern incendiary bomb and the large number that can be released from each raiding

'plane. The burning bombs and the resulting fires can be dealt with as described in Chapter II by the standing Fire Fighting Services, Auxiliary Fire Fighting personnel, the public, or automatically by sprinklers, installed chemical extincteurs or anti-fire bombs.

(e) Splinters and Fragments

This is a very real danger—perhaps the greatest of all to the population not under cover. In some of the raids on London as many as one-third of the total casualties were caused by fragments from our own anti-aircraft fire. Modern concentrations of fire will be much more severe, and thus risks from this hazard will be intensified.

Splinters from bursting bombs and fragments of *dèbris* projected by telekinesis effects on the explosion of H.E. bombs account for the largest proportion of casualties. Degrees of splinter protection afforded by various forms of construction are, however, well known, and these are described in Chapter II.

(f) Blast from High Explosive

High explosive bombs are undoubtedly the chief danger in an air raid. Blast is the shock transmitted through the air when the explosion occurs, and its effects are discussed in Chapter II. Except in the case of direct hit, considerable screening from the effects of blast can be secured in shelters underground.

(g) Demolition of Buildings

This is a real danger to all housed in a town subject to bombardment from the air. It is met by the strengthening of basement shelters and the disposition and protection of entrances and exits generally as described in Chapter VII. A very considerable amount of demolition of buildings must be expected in an attack, as this cannot be avoided by any known means.

(h), (j) and (k) Direct Hits by High Explosive Bombs

The effects of direct hits are devastating and final. The bomb always has the last word and the search for an absolutely bombproof shelter is futile. Were we to provide 100 per cent.

protection against the $\frac{1}{2}$ ton bomb the 1 ton bomb would be used against us. The risk from direct hits will have to be accepted.

General Foulkes, in "Common-Sense and A.R.P.," states that: "In an area within 15 miles of Charing Cross, containing a population of $8\frac{1}{2}$ millions, the odds against a bomb falling within fifty feet of any particular spot are two and a half millions to one!"; but this is hardly a true picture of the risk, as the population is distributed over the area and more than one bomb will be used! Nevertheless, in recent raids in Spain and China only 2 per cent. of the casualties were attributed to direct hits.

Shelters must be of a nature to permit of as little interference as possible with the normal life of the community and national expenditure on passive defence measures must be adjusted to comply with the order of priority the exigencies of the times dictates. The Government discourages the attempt to construct shelters that are completely bombproof and approves of the provision of the best protection possible in the circumstances, observing discrimination in selecting areas where the bulk of the money must be spent.

CIVIL DEFENCE

General Principles of Defence

An air attack may possibly be beaten off by the use of light and speedy fighting 'planes armed with machine guns and by the use of anti-aircraft batteries firing from the ground.

The former will, no doubt, prove to be the first line of active defence and the latter the second. The balloon barrage has considerable value in protecting large cities from aerial attack and is a defensive arm of the fighting services. Passive defence by evacuation, protective construction, fire fighting and gas decontamination constitutes the latest line of defence.

Thus we have—

The civilian in industry;

First aid, gas decontamination, and auxiliary fire-fighting services;

The standing civic control bodies and public services;

Protective construction, gas, splinter and blast proof shelters ;
Balloon barrage ;
Anti-aircraft artillery ;
Aircraft defence services ;
The fighting services

opposing the air raiders.

The Air Force

We have good reason to be proud of the British Air Force, which, in equipment, aircraft, instruments and efficiency, is second to none in the world.

An attacking enemy can expect a hot reception and measure for measure by way of reprisals, and the active engagement of the attacking forces will do much to sustain the morale of the public.

Summary of Comparative Air Power Strengths

The first line strengths of the principal air powers in March, 1937, were estimated as below :—

TABLE III

U.S.S.R.		5,000 machines
Germany		3,500 ,,
Italy		2,750 ,,
France		2,700 ,,
Great Britain—		
Home Defence	1,750	
Overseas	430	
Fleet Air Arm	350	
		2,530 ,,
U.S.A.		2,000 ,,
Japan		2,000 ,,

First line comparisons are however apt to be misleading as reserve power, training and manufacturing resources have a dominating influence.

By June, 1939, it was stated that Russia was equipped to produce planes at a greater rate than Germany, the warplane output of which was said to be 600 a month.

At that date Germany's front line strength was put at 4,200 planes—2,500 of them bombers, Czecho-Slovakia having provided her with 750 machines.

Our production at that time exceeded 1,000 a month, and our first line strength at home and abroad exceeded 3,000 machines.

On the failure of our peace gestures, the world supremacy which we relinquished at the end of the Great War had to be regained and our Air Force has experienced a phenomenal and unprecedented peace time increase.

By March, 1940, the R.A.F. man power will have been increased to five times its 1937 strength, and we are well ahead of programme.

At the start of rearmament we spent a mere 4½ millions on aircraft, but at the present time we are spending at the rate of 100 millions a year on this arm!

Other indications of national preparedness are the proportionate increases in the Reserve of R.A.F. Officers, R.A.F. Volunteer Reserve and the Observer Corps.

"Look at this table, taken from the *Ala d'Italia*. It gives the performance of German first line aircraft in use to-day.

TABLE IV

Bombers.	Cruising speed.		Range.		Armament Bombs
Ju. 88	250 m.p.h.	...	1,250 miles	...	3,100 lb
He. 111	250 m.p.h.	...	930 miles	...	4,400 lb
Do. 17Z	250 m.p.h.	...	500 miles	...	2,200 lb
Ju. 87	200 m.p.h.	...	500 miles	...	1,100 lb

Fighters.	Speed.		Armament.
He. 112	290 m.p.h.	...	2 machine guns and 2 shell guns
Bf. 109	320 m.p.h.	...	3 to 4 machine guns
Bf. 110	350 m.p.h.	...	4 machine guns, 2 shell guns

"From this table it can be said definitely and confidently that every standard British war plane now in service exceeds these German planes in range, speed, armament, quality and quantity." *

Our heavy bombers now weigh over 10 tons, 40 per cent. of which is an effective bomb load. Speeds are 200 m.p.h. and range 1,250 miles.

* *Sunday Express*, April 16th, 1939.

Canada is to manufacture for us four-engined bombers having an all up weight of 30 tons, 10 tons of which would be in bombs. Speeds are said to be 300 m.p.h. and the range without refuelling 5,000 miles. They will be armed with small cannon instead of machine-guns.

In less than two years, at the present rate of development, compared with that in other countries, Britain will have the largest and best air force in Europe. Quality of equipment and excellence in personnel count as much as sheer numbers.

For obvious reasons this aspect of the subject cannot be discussed fully but the data already given may be of general interest.

It is interesting to note that at the time of the armistice Great Britain had 14,000 serviceable machines against Germany's 11,000 and France's 10,000, and that Britain was turning out machines at the rate of 3,500 machines a month—considerably in excess of that of the other two countries [66].

Balloon Barrages

Balloon barrages may be of the circumferential type in which a ring of balloons anchored at about 300 ft. intervals completely encircle the city or of the " field sited " type in which a random arrangement of more widely spaced captive balloons covers the whole area to be protected.

In each case the function is to prevent the low flying approach to the target and to keep raiding planes at heights at which they can be dealt with by interceptor aircraft and anti-aircraft artillery.

Towards the end of the Great War " balloon aprons " were used in the defence of London.

A network of wires was stretched between a number of balloons tethered in a line, but the great height required to-day makes their weight excessive and their use over the extra-high tension electric aerial cables used in the grid system a danger.

Each balloon holds 19,000 cub. ft. of hydrogen, is 64 ft. 2 in. long and 33 ft. in diameter, and is handled by a lorry winch and a crew of ten who can move the balloon at will and haul it down at a speed of 1,400 ft. per minute for repairs or deflation.

Each mobile unit consists of a 30 h.p. six-wheel Fordson

tractor, on which is mounted a Wild winch, operated by a 20 h.p. Ford V.8 engine.

Coupled to the tractor is a four-wheel Brockhouse trailer, with thirty-six red steel cylinders of hydrogen, each holding 600 cub. ft. Each unit weighs 10 tons and moves at 30 m.p.h. It has a crew of ten under an N.C.O., and it is ready to go into action at a moment's notice.

The equipment carried on the Fordson chassis includes everything necessary for the rapid inflation and raising of the balloon.

The balloon itself is packed into a valise standing 3 ft. high. With it are a quick-release filler-coupling; lengths of white canvas gassing hose; a gas valve; a ten-way hydrogen filler; a saw, spade, pick and crowbar, for clearing a site when the balloon is to be moored in the open; sandbags to ballast it during inflation or when moored.

The equipment also includes a chest of screw pickets to receive the ground moorings and designed to resist a pull of 1½ tons, and a megaphone.

Behind this is the winch, round which is wound 5,000 ft. of steel cable—for low barrage.

Each member of the crew has his own job to do; some to clear the site, others to couple the gassing hose, remove the balloon envelope from its valise, couple the hose to the ten-way gas filler, unscrew the hydrogen cylinders, attach the rigging to the winch, and so on. When the balloon is fully inflated, the snatch-brake on the winch is released and the flying cable unwinds itself as the gas lifts the balloon at a speed of about 500 ft. per minute.

The balloons normally float at 10,000 ft. height and can ride a ninety mile per hour gale on an anchor cable of only 3 mm. in diameter. In the near future heights of 25,000 ft. are expected to be reached and the sphere of usefulness thus greatly increased.

Closer spacing of the balloons is not thought to be necessary since bomber wing spans now approach one-third the distance between the wires and the chance of safe "in" and "out" passage is therefore remote.

"Field sited" arrangements of balloons also increase the chance of contact and the electrification of the wires with extra-

high potential makes contact with them fatal. The wires are not visible by day or night.

Decoy balloons charged with explosives can also be fired from the ground when hostile aircraft are in close proximity to them. A "stockade" of captive balloons round London on a ten miles radius would only require 1,100 balloons spaced at 300 ft. apart and would protect 200,000 acres of the Metropolis, the area within the perimeter extending from New Barnet to Croydon and from Barking to Twickenham.

Arranged on the "field sited" plan little more than half this number would protect the same area, but on the other hand more interference with search lights and anti-aircraft gunnery is likely by this arrangement.

Land Batteries

Defence by land batteries of anti-aircraft guns is now a highly scientific organisation.

The guns are of great accuracy, rapid firing and of long range and their manœuvrability is truly astounding.

A few of the problems that beset the anti-aircraft gunner will readily be appreciated.

An approaching target moving at 200 m.p.h. and seen when five miles away will be overhead in the short space of ninety seconds!

The projectile would normally take fifteen seconds to cover the range, so that during the time of flight the target will have travelled 0·83 mile from the position it occupied in space at the instant the gun was fired.

To be effective the shell must burst within about 50 yards of the target, so that extreme accuracy of prediction is necessary to secure a "hit."

Assuming the target continues on the same course at the same speed and at the same altitude the predictions are simplified when the course, etc. is known.

This can only be ascertained after careful range-finding and successive trigonometrical observations on the plane.

The problem is further complicated by the troublesome "corrections" for wind, temperature, barometric pressure, temperature of charge, gun correction due to wear, slant range, droop of trajectory for the appropriate angle of elevation,

compensation for "dead time" of the gun's crew after the automatic setting of the time fuse, etc., to name but a few. The need for both speed and accuracy in field calculations is obvious and in the earlier arrangements calculating slide rules and curves were used to a large extent.

A very complicated but accurate device incorporating a sighting telescope and range-finder mechanically operating compensated calculating machines is now used. This predicter, as it is called, gives the required information in a few seconds, and can be electrically connected to the gun training mechanism which automatically follows the predicter.

Further developments on the basis of ranging from two distant points of observation are anticipated and firing accuracy will become more deadly.

"Spotting" corrections to permit a degree of ranging by direct observation are also being adopted.

Concurrently with the development of speed and increase in normal height of aircraft, the improvement of anti-aircraft ordnance continues. At the time of going to press there is news of a French anti-aircraft gun reputed to have an effective range of eight and a half miles!

The subject is outside the scope of the present work but it is hoped that enough has been said to indicate that although the science of active defence is highly developed the need for thoroughness in passive defence precautions is a very real one.

Passive Defence

Dispersion of the population over a wide area to underground gas-proof shelters is the best means of passive defence. As, however, there may be no more than seven minutes warning of an air raid emergency shelters will need to be provided near all centres of human activity.

The use of Tube tunnels as air raid shelters is wisely forbidden until the proper precautions against flooding are taken. Some restriction or regulation of their use is essential.

The responsibility of providing real shelters—not death traps—is with local authorities, and it is the duty of each individual householder to do all he possibly can himself for the protection of his family and his own home.

All managers of factories and business premises employing over 50 operatives are urged by the Air Raid Precautions Dept. to prepare their own schemes for protection and to obtain from the Department constructive criticisms of the proposals. Indeed, under the provisions of the Civil Defence Act such measures become obligatory.

In recent air raid exercises in Berlin the whole population of the city were under suitable cover within five minutes and in any large city similar arrangements ought to be made.

The authorities have organised emergency means of evacuation where necessary and rescue parties and decontamination services supplement volunteer corps of Air Raid Wardens.

Wardens' chief duties are to advise their fellow citizens on the officially recommended precautions against air raids ; and in time of war to assist them immediately in any trouble resulting from air raid damage, to know how to begin relief measures and where to apply for help, and generally to act the part of a good neighbour.

It is the duty of each individual householder to see that all who normally occupy the premises have a gasproof, splinter and blast-resisting shelter to which they could immediately repair in an emergency, and the public are urged to take cover in their own shelters and *not* to congregate in public buildings.

A very great responsibility rests upon the members of all air raid precautions services to set an example of quiet courage and cool resourcefulness in emergency, and this can only be obtained by careful training and a clear appreciation of all the facts.

Prompt action may save life and property and will defeat the object of the raid.

CHAPTER II

BOMBS

Definition

A BOMB is a container for high explosive, gas or incendiary mixture, provided with an automatic means of detonating, distributing or igniting the filling.

Function

The military function of a bomb is to perforate protective covering or to penetrate a target, there to encompass destruction by means of shattering power, emission of war gas or by incendiary effect. When special penetrative power is required, bomb cases must be made strong enough to withstand the shock of impact against hard surface targets and to penetrate intact for delayed-action detonation.

For light civil buildings, submarine attack or against personnel in the open a light case bomb is all that is necessary, thus enabling the weight of the filling to be a high proportion of the total weight of the bomb. Thus light case bombs have a high charge/weight ratio.

In an air bombardment the three kinds of bombs might be used explosive bombs, incendiary bombs and gas bombs, and a mixed load aggregating two or three tons may be carried by each bomber.

Classification

The author has found the following classification of bombs convenient :—

1. High Explosive Bombs

(*a*) *Armour Piercing.* Heavy case. Low charge/weight ratio delay-action fuse ; principal use against fortifications for destruction by penetration, brisance, blast and splinters.

(*b*) *Semi-Armour Piercing.* Heavy case. Low charge/weight

ratio delay action fuses; principal use against substantial buildings for destruction by penetration, telekinesis, blast and splinters.

(c) *Demolition.* Medium case. Percussion fuse; use against buildings and light fortifications, penetration, blast and splinters.

(d) *General Purpose.* Medium case. Percussion fuse; use against civil and industrial communities for impact, blast and splinters.

(e) *Anti-Submarine.* Light case bomb, delayed-action fuse; depth charge effect, principally of concussion.

(f) *Fragmentation.* Light case bomb with light percussion or graze fuse; principally used against personnel in the open with blast and splinter effects.

2. Incendiary

(a) *Medium case intensive type* designed to penetrate and set fire to buildings and bring the incendiary agent into direct contact with the materials to be damaged.

(b) *Heavy case intensive type* for attack on solidly constructed fortifications.

(c) *Medium case scatter type* containing groups of smaller incendiary agents scattered by the explosion of the bomb to set fire to readily combustible materials, such as hutments, grain fields, woods, etc.

3. Gas Bombs

(a) *Thin case chemical bombs* with percussion fuse.

Forms of Bombs

Bombs were originally spherical with the object of securing the maximum charge/weight ratio, but their penetrative capacity was low, and as a consequence the streamline shape was adopted during the Great War. The cylindrical type is now more generally used, since tests conducted at proving grounds and in wind-tunnels indicate that the resistance encountered in flight by well-designed cylindrical bombs is no greater than that of the streamline type of high aerodynamical refinement.[156]

The full effects of streamlining cannot be obtained, since

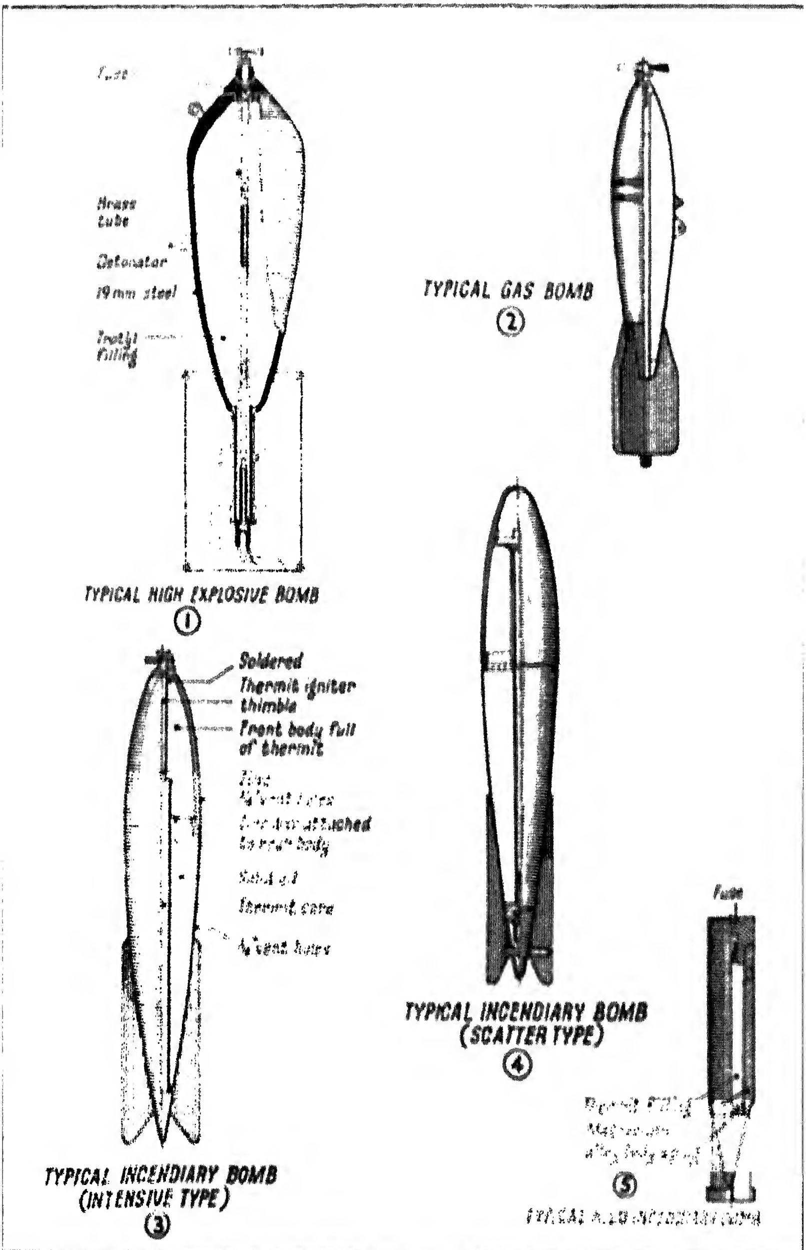


FIG. 3.—Typical details of bombs.

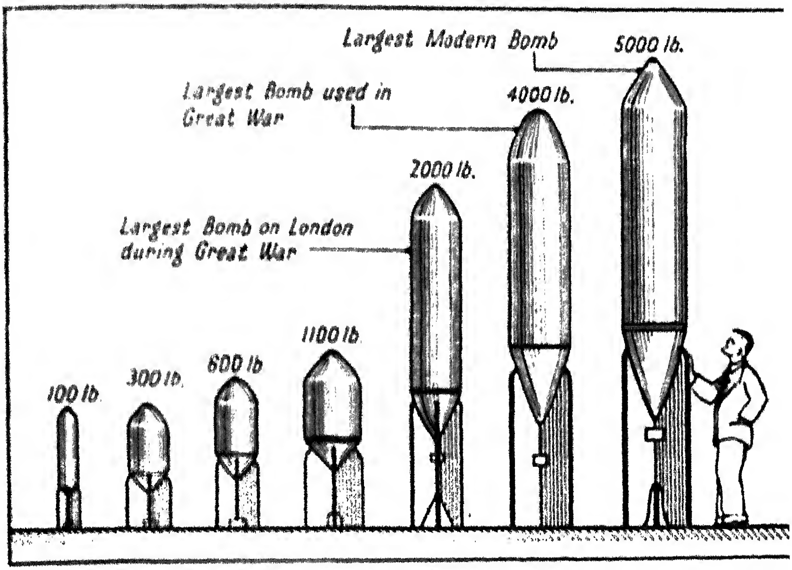


FIG. 4.—Diagram illustrating the growth of the bomb since the 1914–18 war.

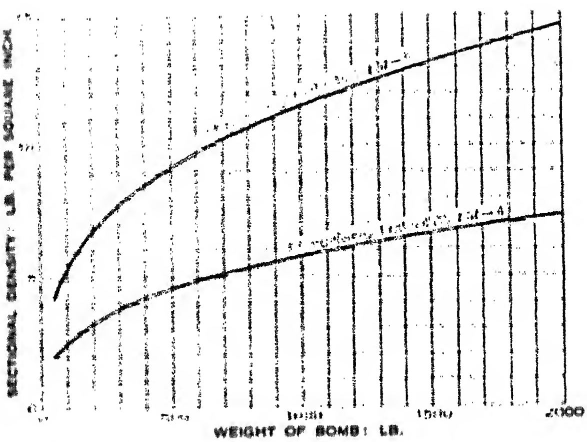


FIG. 5 Variation of sectional density with bomb-weight.

the necessary incorporation of lugs, detonation control gear and stabilising fins offset the theoretical advantages.

Fig. 3 gives the approximate outlines of various types of

bombs, and Fig. 4 the approximate range of sizes indicating the growth of the bomb since the Great War. The ratio of length to diameter will normally be between four and six to one.[159]

The Charge/Weight Ratio of High Explosive Bombs

The charge/weight ratio of cylindrical high explosive bombs depends almost entirely upon the wall thickness in relation to the diameter, *i.e.*, the thickness/diameter ratio, and only to a small extent upon the ratio of length to diameter.[159]

The following table shows the relation between the respective functions for cylindrical H.E. bombs :—

TABLE V

Charge/weight ratio %.	Thickness/diameter ratio.		Densities in lb. per cubic inch.	
	Length/diam. = 4.	Length/diam. = 6.	Length/diam. = 4.	Length/diam. = 6.
10	0·158	0·167	0·182	0·160
20	0·100	0·108	0·140	0·150
30	0·060	0·070	0·110	0·120
40	0·045	0·049	0·095	0·100
50	0·030	0·035	0·082	0·087
60	0·022	0·025	0·073	0·078
70	0·017	0·018	0·068	0·070
80	0·010	0·012	0·060	0·061

Since the sectional area of the bomb has a dominating influence upon its penetrative power, the sectional density—*i.e.*, the weight in pounds per square inch of cross-section—is of greater importance than the density. The sectional density of H.E. bombs of various weights may be ascertained by reference to Fig. 5, that for incendiary bombs varying between ½ lb. per square inch for the lightest bombs to 2 lb. per square inch for the heaviest " hard nose " incendiaries.

Table VI gives particulars of bombs obtained from foreign sources.

TABLE VI

TABLE GIVING PARTICULARS OF BOMBS [162]

		[illegible]		General-purpose Explosive Bombs.							Delayed-action H.E. Bombs.							
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	50	10[illegible]	[illegible]	[illegible]	25[illegible]	250	300	400	500	700	900	1000	1800	Kg.
Germany, 1918	Length		[illegible]			1730	[illegible]			—	—	2750	—	—	—	—	4100	—	mm
	Max. diameter		[illegible]			180	[illegible]			—	—	370	—	—	—	—	570	—	mm
	Total weight		[illegible]			50	[illegible]			—	—	300	—	—	—	—	1000	—	kg.
	Weight of explosive		[illegible]			23				—	—	180	—	—	—	—	680	—	kg.
	Number of detonators		[illegible]			1	[illegible]			—	—		—		—	—	[illegible]	—	No.
England, 1918	Length	[illegible]		8[illegible]		946	[illegible]			152[illegible]	—			[illegible]	—	—	—	—	mm
	Max. diameter	[illegible]	—	2[illegible]		274	[illegible]		—	457	—				—	—	—	—	mm
	Total weight	[illegible]	—	[illegible]	—	52·[illegible]	[illegible]	[illegible]	[illegible]	250	—				—		—	—	kg
	Wt. of explosive	[illegible]	—	[illegible]	—	12·7			—	81·[illegible]	—				—		—	—	kg
	No. of detonators	[illegible]	—	[illegible]	—	2	[illegible]	[illegible]	[illegible]	[illegible]	—				—		—	—	No.
Finland, 1933	Length	—	[illegible]	—	[illegible]	1300	15[illegible]		—	—	—		—		—		—	—	mm
	Max. diameter	—	[illegible]	—	[illegible]	178	[illegible]		—	—	—		—		—		—	—	mm
	Total weight	—	[illegible]	—	[illegible]	50	[illegible]		—	—	—		—		—		—	—	kg.
	Wt. of explosive	—	[illegible]	—	[illegible]	25	[illegible]		—	—	—		—		—		—	—	kg.
	No. of detonators	—	[illegible]	—	[illegible]	2	[illegible]		—	—	—		—		—		—	—	No.
France, 1934	Length	[illegible]	—	—	—	1510	15[illegible]		—	—	—	17[illegible]	2100		3050		—	3800	mm
	Max. diameter	[illegible]	—	—	—	200	3[illegible]		—	—	—	[illegible]	41[illegible]		420		—	530	mm.
	Total weight	[illegible]	—	—	—	50	1[illegible]		—	—	—	[illegible]	4[illegible]		700		—	1800	kg.
	Wt. of explosive	—	—	—	—	—	—		—	—	—		—		—		—	—	
	No. of detonators	1	—	—	—	2	[illegible]		—	—	—	[illegible]	[illegible]		2		—	2	No.
U.S.A., 1934	Length	[illegible]	—	—	—	1493	—	14[illegible]	—	—	1803	—	—	215[illegible]	—	32[illegible]	—	3900	mm
	Max. diameter	152	—	—	—	178	—	3[illegible]	—	—	500	—	—	[illegible]	—	4[illegible]	—	540	mm
	Total weight	[illegible]	—	—	—	55·3	—	1[illegible]	—	—	254	—	—	[illegible]	—	9[illegible]	—	1800	kg.
	Wt. of Explosive	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1000	kg.
	No. of detonators	1	—	—	—	2	—	2	—	—	2	—	—	2	—	2	—	2	No.

In 1939 the British Home Office published the following table of typical dimensions of aircraft bombs [5]:—

TABLE VII

Bomb	Length in Feet		Diameter in inches	Sectional Density lb. per square inch
	Overall	Bomb Carcass		
2,000 lb. light case .	14	9	24	4·4
1,100 lb. heavy case .	6	4	12	9·7
550 lb. medium case .	5	4	15	3·1
220 lb. " " .	4½	2	10	2·8
100 lb. " " .	4	2	9	1·6
20 lb. anti personnel	2	1	5	1·0

Typical Bombs

Typical bombs are illustrated in Fig. 3. No. 1 is a 500 lb. high explosive bomb of English manufacture. It is a streamline shape with two fuses and a number of detonators contained within a brass tube, which passes throughout the length of the bomb. The steel body is pressed out and the fittings are attached as shown; the fins are in metal, the length of the bomb being 6 ft. and the diameter 18 in.; the filling is trotyl.

The second illustration is of a typical gas bomb of streamline form and of American manufacture. It has a light pressed case, a fuse with the usual wind vane safety device and iron fins at the rear.

No. 3 is a typical incendiary bomb of the intensive type as manufactured in America for the U.S. Air Service. The figure illustrates a 100 lb. bomb of the intensive type filled with thermite and solid oil as the principal incendiary materials. The body consists of two main parts—steel nose and the sheet-zinc body and the sheet-iron vanes attached. Solid oil is run into the body in a heated condition and solidifies when cooling. Ignition is effected either by a powder flash or by a bullet from the service cartridge. On landing, the thermite in the front part of the body is ignited and the great heat generated thereby serves to volatilise the oil, which quickly becomes ignited, burning with a tremendous burst of flame. Practically

the whole of the materials in the bomb are burnt up when the bomb functions.

The fourth illustration is of a typical incendiary bomb of the scatter type. It contains units consisting of waste tied into balls and saturated with inflammable material, such as a mixture of crude turpentine and carbon disulphide. The units are usually about 3 in. in diameter in the 40 lb. bomb. When the bomb lands, ignition and ejection of the units are effected by an explosion of black powder in the nose of the bomb. A simultaneous explosion of a smaller amount of powder in the rear assists in scattering the units and in bursting the bomb casing.

The fifth illustration is of the kilo-electron bomb of British manufacture. This type of bomb consists of a thick-walled tube, 9 in. long and 2 in. diameter, made of an alloy of magnesium with a small proportion of aluminium. On one end of this tube there is a tail 5 in. long to steady the bomb in flight. The tube is filled with a priming composition of the thermite type. The bomb is fitted with an igniter, which may be situated either in the nose or in the rear end of the tube.

The bomb weighs about 2 lb. 2 oz., and, with the exception of a few ounces in the tail and igniter, there is no dead weight, the whole being incendiary material.

The bomb functions on impact, a needle in the igniter being driven into a small percussion cap which ignites the priming composition. The bomb does not explode.

It should be noted that, although this bomb is often called a thermite bomb, or a thermite electron bomb, the main incendiary agent is not the thermite composition but the magnesium tube, which is not in itself readily inflammable. The priming composition burns for forty to fifty seconds at a temperature of about 2,500° C., and its great heat serves to melt and ignite the magnesium tube. The molten magnesium burns for ten to fifteen minutes at a temperature of about 1,300° C.; it may remain active for as long as twenty minutes and will set fire to anything inflammable within a few feet.

During the first fifty seconds or so, while the priming composition is still burning, the bomb looks very violent; jets of flame are emitted from vent holes, and pieces of molten magnesium may be thrown as far even as 50 ft. After the first

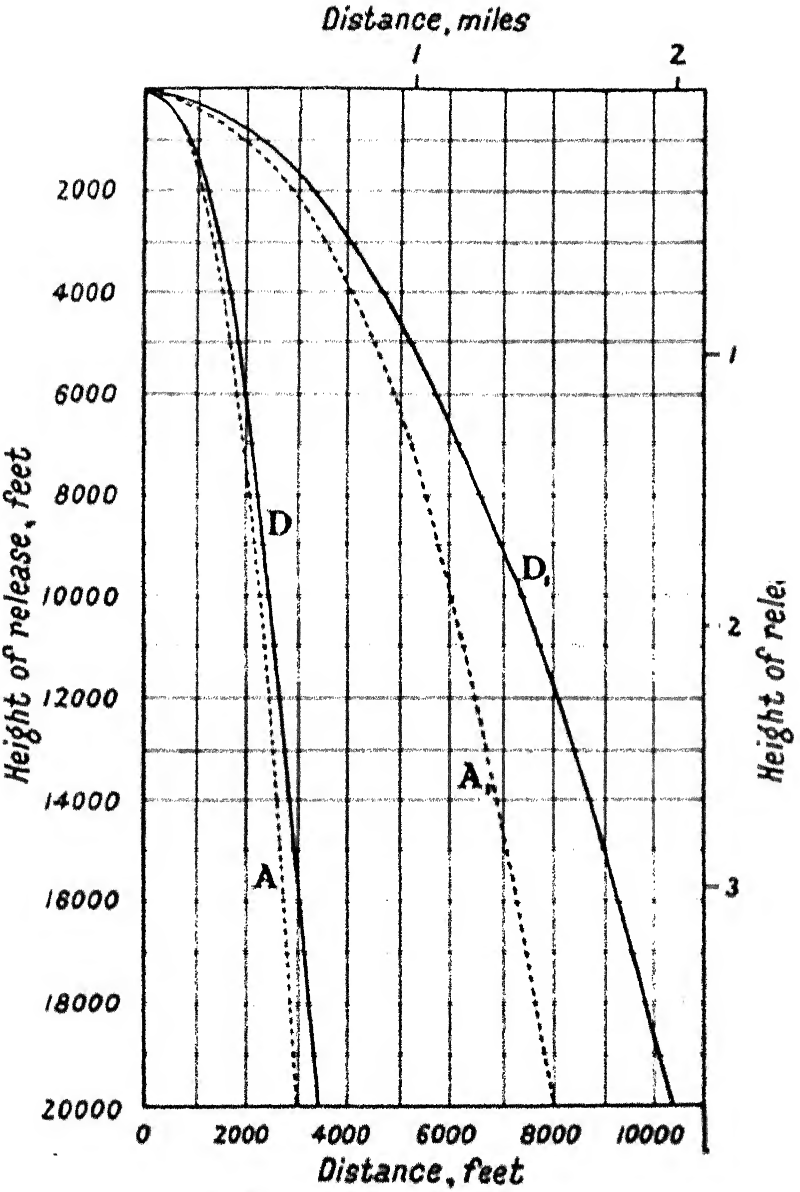


FIG. 6.—Trajectories of falling bombs.
Curve A is for small incendiaries released at 100' per sec. horizontal speed.
Curve A_1 is for small incendiaries released at 300' per sec. horizontal speed.
Curve D is for heavy-case bombs released at 100' per sec. horizontal speed.
Curve D_1 is for heavy-case bombs released at 300' per sec. horizontal speed.

minute the bomb becomes less active because the magnesium tube melts and the pressure within is released.

The thermite composition contains its own oxygen and so cannot be extinguished by smother, but the magnesium must get its oxygen from the air or surrounding materials in order to burn.

The bombs would not be dropped singly, but would be released from containers each holding ten to twenty bombs. The contents of several containers can be released simultaneously.

The bombs spread out as they fall, and a group of bombs dropped simultaneously from 5,000 ft. would cover an area of about 100 yards square.

Angle of Approach

Bombs rained down from aircraft seldom if ever approach the earth in a truly vertical direction.

The forward speed of the aircraft imparts the same horizontal velocity to the released bomb, and except for the effects of wind and air resistance this velocity remains constant throughout the time of flight of the bomb.

The vertical velocity steadily increases by the acceleration due to gravity, with the result that bombs fall through a curved path becoming more vertical as the height of release increases.

The air resistance and its retardation of both components of the velocity varies with the velocity, the sectional density and the shape of the bomb and with the density of the air. Fig. 6 shows the approximate trajectories of bombs of sectional densities of from ½ to 15 lb. per square inch released from any height up to 20,000 ft. from aircraft travelling with a horizontal velocity of from 100 ft. per second to 300 ft. per second (68 to 204 miles per hour). Thus it will be seen that the angle of approach of a bomb may be anything from 30 degrees for a bomb of heavy sectional density released from low-flying aircraft to 87 degrees to the horizontal for light sectional density bombs released from a great height.

Bombs may be released at any altitude between, say, 25,000 ft. and 1,000 ft., or slightly under, and the angle of incidence will be more influenced, at the lower points of release, by the horizontal speed of the aircraft. Released at a few hundred feet altitude the bomb strikes almost horizontally with the speed of the aircraft.

The Dynamics of Bombing

The following fundamental formulae will be found of interest and use :—

$$V = U + ft \qquad \therefore t = \frac{V - U}{f}$$

$$S = \frac{V + U}{2} \times t \qquad \text{and } t^2 = \frac{V^2 - 2VU + U^2}{f^2}$$

$$S = Ut + \tfrac{1}{2}ft^2$$

$$S = \frac{UV - U^2}{f} + \frac{V^2 - 2VU + U^2}{2f}$$

$$S = \frac{V^2 - U^2}{2f}$$

$$\therefore V^2 = U^2 + 2fS$$

$$P = mf.$$

$$\text{K.E.} = P \times S \text{ ft. poundals}$$

$$= mfS \qquad S = \tfrac{1}{2}ft^2$$

$$= \frac{mf^2t^2}{2} \qquad V = ft. \quad \therefore t = \frac{V}{f}$$

$$= \frac{mf^2V^2}{2f^2}$$

$$= \tfrac{1}{2}mV^2 \text{ ft. poundals}$$

$$\text{or } \frac{WV^2}{2g} \text{ ft. lb.}$$

where "m" is the mass in lb.
"P" is the force in poundals.
"f" is the acceleration in feet per second per second.
"g" is the acceleration due to gravity.
"U" is the initial velocity in feet per second.
"V" is the final velocity in feet per second.
"t" is the interval of time in seconds.
"S" is the distance traversed in feet.
"W" is the weight in lb.
K.E. is kinetic energy.

Striking Velocity

The arrival-velocity of a bomb depends upon—

(*a*) The height of release.

(*b*) The direction and velocity of the aircraft at the instant of release.

(*c*) The air resistance.
(*d*) Sectional density.
(*e*) The shape of the bomb.

The air resistance imposes a limit to the striking velocity, since a terminal velocity is reached when the air resistance equals the weight of the bomb. The resistance varies *inter alia* with the square of the velocity.

The terminal velocity

$$= Vo\sqrt{\frac{Q}{a}}$$

Where Vo is the terminal velocity corresponding to unit values of Q and a, its value usually being 600 700 ft. per second. Q is the sectional density. a is a coefficient which depends upon the form of the bomb and the velocity.

Its numerical value is approximately unity for velocities below 800 ft. per second, increasing to a maximum of 4 at 1,500 ft. per second, beyond which the value of the coefficient decreases again.

The striking velocity of bombs in practice will vary between 400 ft. per second for light incendiary bombs released at low altitudes and 1,500 ft. per second for bombs of high sectional density released at an altitude of 50,000 ft.

The effect of dive-bombing is to impart an initial vertica- component to the velocity of the bomb, thus increasing the striking velocity. The horizontal component of the velocity is reduced and the obliquity of impact on a horizontal surface reduced.

TABLE VIII

Height of Release. Ft.	Angle of Impact. Degrees with the Vertical.	Striking Velocity. Ft. per sec.
1,000	46	390
3,000	33	520
5,000	26	610
7,500	22	710
10,000	19	800
12,500	17·5	880
15,000	16	950

Table VIII gives the approximate striking velocity and the angle of arrival for a bomb released from a plane flying at 200 m.p.h. horizontally and at the altitudes given.[8]

The Time of Fall of Bombs

The duration of fall of bombs does not vary greatly with their sectional density and is also practically independent of the air speed.

It may be calculated approximately from the formula

$$\text{Time of fall in seconds} = \frac{\sqrt{\text{height of release in feet}}}{4}$$

Thus a bomb released at 16,000 ft. altitude would take $\frac{\sqrt{16{,}000}}{4} = 31{\cdot}6$ seconds to reach ground level.

Brief particulars of various types of explosive bombs are given on p. 29.

According to a French authority, explosive bombs cost three hundred times as much per ton to manufacture as gas bombs, and fifteen times as much as incendiary bombs.[67]

There is little doubt however that the cost of explosive bombs weighing more than half a ton is so high, and the number of them which could be carried by each aeroplane is so small, that their use will be reserved for objectives of great military value, and they will probably not be used on civil populations at all.

The table below shows the advantages of the smaller bomb.

Table IX

Effect of a Ton of Explosive Bombs on a Mass of Concrete [67]

Weight of Bomb, kg.	Number of Bombs.	Radius of Destruction. ft. in.	Area Destroyed by each Bomb. Sq. ft.	Total Area Destroyed per ton of Bombs. Sq. ft.
1,000	1	6 6	136	136
250	4	4 3	57	228
100	10	3 0	27	270
50	20	2 4	16	320

EXPLOSIVE BOMBS AND THEIR EFFECTS

Generally

Explosive bombs resemble artillery projectiles in their general effects, but as they are simply released from aircraft and are not subjected to the shock of discharge experienced by the shell in the gun, they do not need to be made so strong as the latter. In shells, especially those of the armour-piercing kind, only about 10 per cent. of the total weight is available for the high explosive charge, whereas in explosive bombs 25–75 per cent. of the total weight may consist of the high explosive known as Tri-nitro-toluene (T.N.T.).

Explosive bombs may be of two kinds :—

A. *Fragmentation bombs*, which are arranged to explode immediately upon impact so as to produce a blast effect with the minimum of penetration, thus increasing the area of effectiveness.

Casualties are caused by flying fragments of the case of the bomb as well as by concussion due to the explosion itself. Considerable material damage is also caused by the blast.

When such a bomb strikes at a large angle of incidence to the vertical, fragments are blown upwards and cover a much larger area.

Splinters may be thrown out with velocities up to 5,000 ft. per second and can cause death to people as far as 400 yards away from the burst.

The thickness of structural materials required to resist the penetration of splinters from fragmentary bombs depends of course upon the distance from the burst.

Protection against splinters from 500 lb. bombs bursting not less than 50 ft. away, according to Home Office recommendations, is listed in Table X on p. 38.

B. *Demolition Bombs*. Demolition bombs are fitted with delayed action detonators in order that considerable penetration shall take place before explosion. They may weigh as much as 5,000 lb. and their destructive effect is increased by the " restraint " caused by the earth or structure into which the bombs penetrate.

A.P. (armour-piercing) or S.A.P. (semi-armour-piercing)

TABLE X

Material.	Thickness.	Remarks.
Mild steel plate .	1¼"	Special steels may give increased resistance.
Stock bricks in cement mortar	13½" solid 13½" hollow	2" cavity.
Unreinforced concrete (not weaker than 6 : 1 mixture)	1' 4"	
Reinforced concrete	12"	Normal structural reinforcement.
Reinforced concrete	10"	Specially reinforced to resist the punching shear effect of the splinters which induces tensile stresses between the front and rear faces of the concrete wall. Rectangular links connecting front and back reinforcement of ½" diameter rods at 12" centres is a suggested arrangement which has been tested successfully.
Sand or earth or coal dust revetments.	2' 6"	This should be the minimum thickness, for example, at the top of a traverse or revetment.
Coal (in lumps) .	2' 6"	
Shingle (or ballast) revetments, contained between wood or C.G.I. sheeting.	2'	A sandwich of shingle between sheeting.
Shingle revetments contained between steel plates. Front steel plate ½" thick, back plate ⅛" thick	10"	

bombs may not carry more than 10 per cent. explosive and the fragmentation effect is reduced by penetration.

The effect of such a bomb exploding underground is similar to that of a mined charge.

The A.P. bomb and the S.A.P. bomb are specially designed for attacking very highly resistant targets, so that against ordinary structures the use of the lighter case bomb may be expected, though the S.A.P. bomb may be used occasionally as well.

Major W. C. Sherman of the U.S. Army, in his book, "Air Warfare," gives the following figures for the relative performance of demolition bombs in production in 1926.

The L.C.C. official records published in 1920 under the title of "The Council and the War," show that the 1,000 kilo bomb

TABLE XI

Weight of Bomb in pounds.	Diameter of Crater in feet.	Depth of Crater in feet.	Diameter of Danger Zone in feet.
100	12	6	200
300	20	6	300
600	25	7	400
1,100	30	7	600
2,000	40	14	1,200
4,000	65	16	2,400

dropped in London from a giant aeroplane on the night of March 7th/8th, 1918, on Nos. 61–67 Warrington Crescent, Maida Hill, N.W., totally demolished four houses, seriously damaged twenty others within a radius of 210 ft., and slightly damaged one hundred and nineteen additional houses within a radius of 600 ft. This confirms the figures in the above table. The present day 5,000 lb. demolition bomb must have a destructive zone of 3,000 ft. diameter on an exposed site and the future may have in store for us a yet more destructive and terrifying monster.

Fig. 7, giving graphs showing the probable effects of demolition bombs, is plotted from the available test results but must be taken as approximate only.

It will be found of use in interpolation and extrapolation within reasonable limits.

The effects of the bomb must depend upon the nature of the target, the angle of incidence and the velocity of impact.

It will be noticed that all curves show a characteristic upward turn at the lower end—the smaller calibre bombs give relatively greater effects weight for weight. The bomb most frequently used weighs 500 lb.

In Barcelona ¼ ton "percussion" bombs made craters about 4 ft. deep and demolition bombs of the same weight craters 23 ft. deep.[114]

A 500 lb. bomb fitted with a percussion fuse when falling on a modern multi-storey building would probably detonate on the

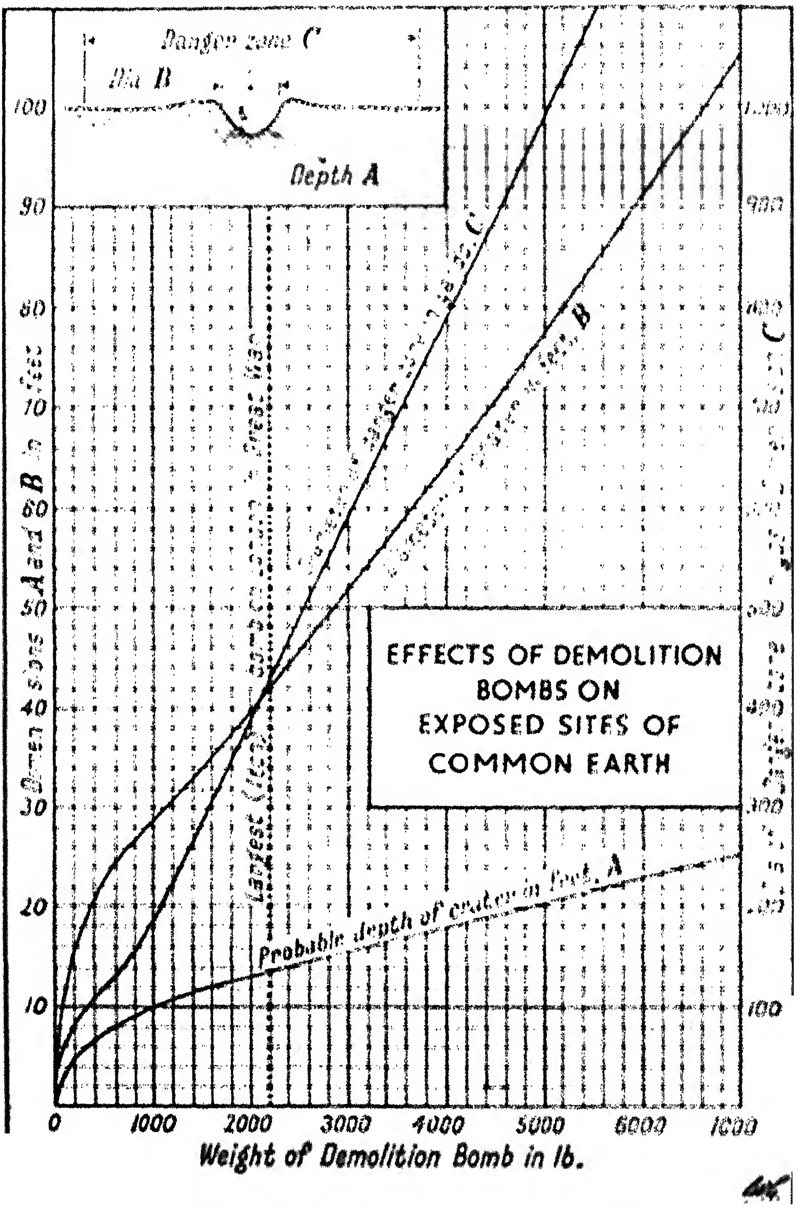


FIG. 7. Graph showing the probable effects of high explosive demolition bombs on exposed sites of common earth.

top floor, bringing down a considerable part of the building with it.

A similar bomb, fitted with semi-armour-piercing nose, would penetrate to the basement before detonating and do considerably more damage.

Protection from 500 lb. high explosive bombs fitted with percussion fuses would be afforded by a 5 ft. thickness of highly reinforced concrete, whereas to secure protection from a 500 lb. bomb with semi-armour-piercing nose a shelter 60 ft. below ground would have to be constructed, or the basement of a building roofed with 15 ft. of reinforced concrete.

When a concrete shelter is exposed it should be constructed of a 22 in. thickness of reinforced concrete to resist the 25 lb. high explosive bomb and light incendiary bomb.

The Germans confirmed that detonating bombs of 300 to 500 kg. used by the British were capable of destroying multi-storey buildings. A 300 lb. demolition bomb struck the sea 275 ft. away from, but sunk, a submarine submerged 60 ft. below the water.

The incompressibility of water makes it the ideal medium for the transmission of waves of concussion, and demolition bombs dropped in water have the effect of depth charges.

A 120 lb. bomb sank ex-German submarine "V.117," and the concussion damaged the condenser system of a ship one mile away.[66]

100 300 lb. bombs destroyed all the steelwork above water line of ex-German cruiser *Frankfurt* and a 600 lb. bomb sank her.

Four bombs of 2,000 lb. dropped in rapid succession on ex-German dreadnought *Ostfriesland* lifted her 10 ft. out of the water before she sank.

Twenty-eight tons of demolition bombs were needed to destroy a reinforced concrete bridge in America, 1,000 ft. long and 20 ft. wide, weights below 1,000 lb. being practically ineffective.

On solid rock and mass concrete high explosive bombs have little effect, but a demolition bomb may throw up from 500 to 900 times its own weight of earth.

Full-scale tests of the effect of a 500 lb. bomb on the service mains and sewers below a typical London street give the following results :—

(*a*) All mains were shattered ;
(*b*) Cast iron pipes were breached locally ;
(*c*) Joints of steel mains were damaged for considerable distances ;
and (*d*) A sewer two bricks thick was cracked.[114]

Forces Exerted by Bombs

The following are the forces to be considered in structural defence against direct hit by high explosive bombs :—

(*a*) Impact of bomb.
(*b*) Penetration of bomb.
(*c*) Fragmentation and penetration of splinters.
(*d*) Explosive forces.
  (1) On impact.
  (2) In an enclosed space.
  (3) After penetration into a yielding material.
  (4) In close contact.
(*e*) The accompanying wave of concussion.

(*a*) *Impact*. The energy of impact of bombs may be calculated from the formula

$$KE = \tfrac{1}{2}mV^2 = \frac{WV^2}{2g}$$

where W is the weight of the bomb in lb.
V is the striking velocity in feet per sec.
and g is the acceleration due to gravity (32·2 ft. per second per second).

Thus in the case of a 500 lb. bomb having a striking velocity of 1,000 ft. per second, the energy of impact would be 7,800,000 ft. lb. approximately. An approximate idea of the energy of impact may be obtained by calculating the potential energy in the weight of the bomb at the instant of release. Thus a 500 lb. bomb at 16,000 ft. altitude would have a potential energy of 500 × 16,000 = 8,000,000 ft. lb. Its kinetic energy at impact would, however, be less than this owing to the effect of air resistance.

The energy of impact is concentrated upon the actual area of impact on the target unless penetration through or into a yielding material first takes place and the impact load be thus distributed.

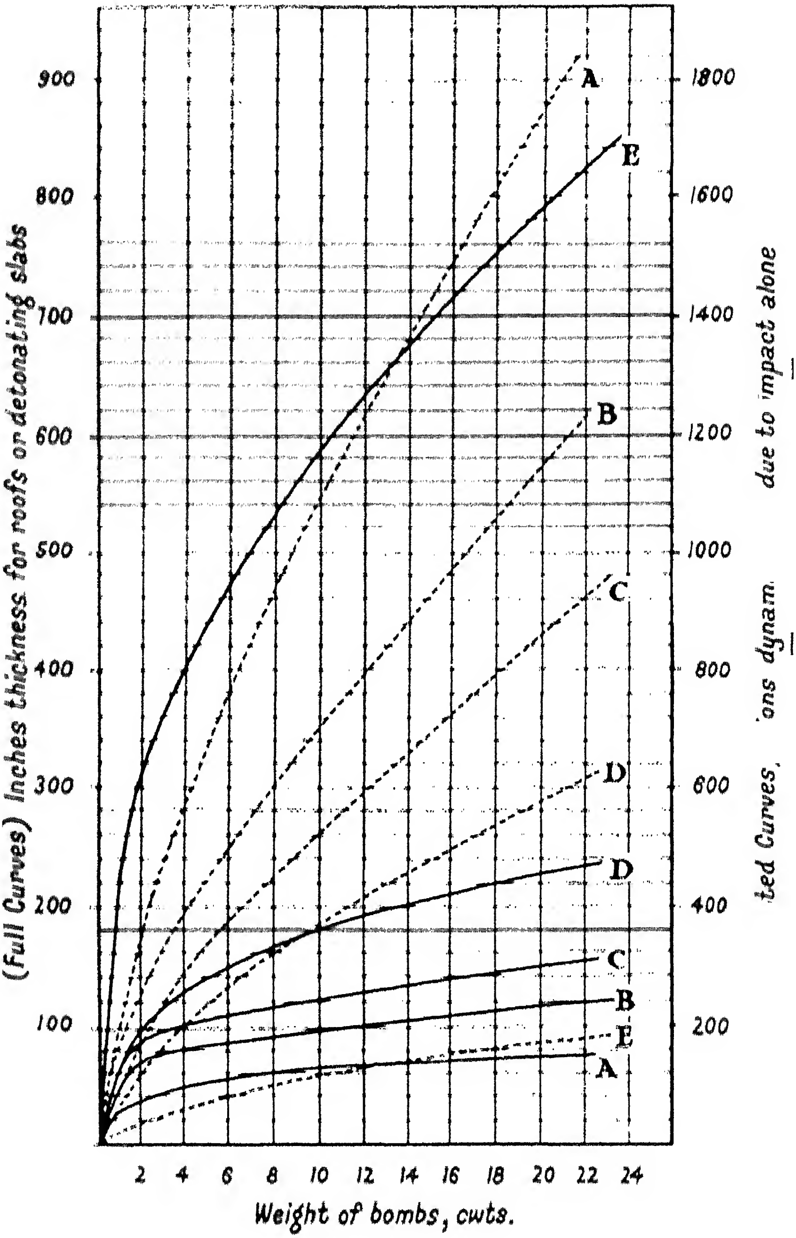


FIG. 7A.
(For explanation see overleaf.)

[To face p. 44.

EXPLANATION OF FIG. 7A.

Curve
- A is for specially reinforced concrete.
- B „ „ ordinary reinforced concrete.
- C „ „ mass concrete.
- D „ „ brickwork or masonry.
- E „ „ normal earth.

(Bomb Sectional Density 4.5 lb. per sq. in. av.)

By "specially reinforced concrete" is meant concrete reinforced in both directions with ½ in. to ¾ in. diameter rods at 6 in. centres. This cross reinforcement is to be in layers 6 in. to 8 in. apart and stirrups or bindings at right angles to the main reinforcement of not less than four ½ in. diameter rods every square foot of soffit.

The thickness of slab for full protection can be read off from the scale on the left hand side of the figure, using the full curves.

On the right hand side of the figure, and using the dotted curves, the dynamic load in tons caused by penetration to one third of the thickness for full protection can be read off.

Thus $$KE = \frac{WV^2}{2g} = Pd$$

where "P" is the average force in lb. causing penetration to "d" ft. assumed to be one third of the thickness for total protection.

For a 1 ton bomb arriving at 500 ft. per sec. penetrating $\frac{79 \text{ in.}}{3}$ into specially reinforced concrete,

(See Fig. 7A, full curve A.)

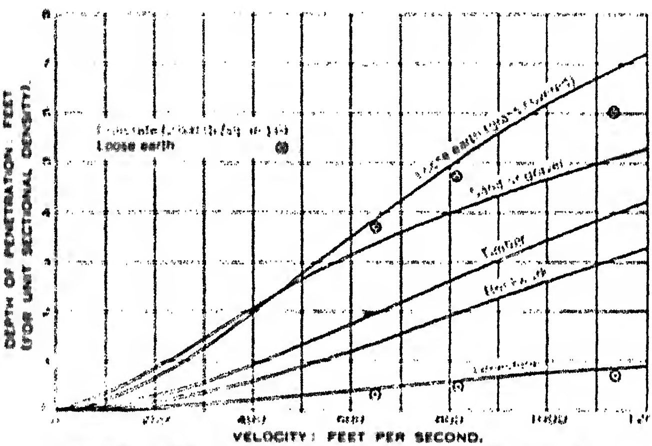
$$P = \frac{1 \times 500 \times 500 \times 3 \times 12}{2 \times 32.2 \times 79} = 1{,}770 \text{ tons}$$

(See Fig. 7A, dotted curve A.)

The curves in Fig. 7A refer to an arrival velocity of 500 ft. per sec. If a slab of weaker material is used, requiring correspondingly more thickness to prevent penetration, the force will be less in proportion. Conversely, if armour plate or other material requiring less thickness to prevent penetration is used, the force will be correspondingly greater. The force varies with the weight of bomb, the square of the velocity, and inversely with the thickness of the detonator slab needed to prevent penetration.

(*b*) *Penetration.* When the bomb completely perforates a protective diaphragm without detonation the hole made through it is about the size of the bomb, but when the objective is sufficiently thick to prevent perforation partial penetration takes place and a crater is formed. The zone of the crater depends upon the characteristics of the material, but is usually much greater than the sectional area of the projectile.

Before penetration occurs a flat cone of material is forced off from the other side of the material hit, and the diameter



Curves: based on results of Metz Committee (1839–40).
Points: based on values given by Bazant (1937).

FIG. 8.—Depth of penetration (for unit sectional density and velocity).

(*Courtesy Inst.C.E.*)

of this cone is sometimes as much as ten times that of the crater itself. The effect of impact varies considerably with the physical properties of the material. When a projectile penetrates water great volumes are thrown out from the point of impact with explosive force, and a bullet fired into damp clay excavates a crater several hundred times its own size. This effect is shown in the case of sand and gravel, which have a greatly increased resistance to penetration at the higher velocities of impact.[157]

A bomb which strikes a material obliquely tends to preserve a curved path through the objective, thus reducing the depth of penetration.

Curves [159] giving the depths of penetration of bombs for unit sectional density and with normal incidence on various materials are given in Fig. 8. Thus the depth of penetration into timber by a bomb having a sectional density of 1 and an impact velocity of 400 ft. per second would be 12 in., and for a sectional density of 3 lb. per square inch the penetration into wood would be $3 \times 12 = 36$ in. for the same impact velocity.

The resistance to penetration of concrete depends upon its compressive strength, and Fig. 9 shows the relation found to exist from an analysis of experimental observations by

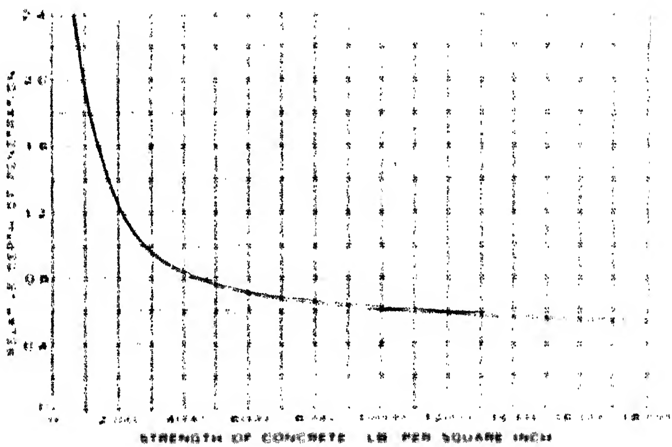


FIG. 9.—Depth of penetration and compressive strength of concrete.

(Courtesy Inst. C.E.)

Skramtajew. The method of determining the thickness required for the roofs of bomb-proof shelters is to multiply the depth of penetration by a constant.

The Russian Army Engineers multiply by 2·77 for shells; the Italians by 2·84 for shells and 3·8 for bombs. In the Belgian authority Petry's R is a variable ranging from 2·8 to 4·5 for different target materials and weights of bombs. These formulæ give values more or less in agreement with practical results and make allowance for the disruptive effects of the explosion (see also Chapter XI).

The following table is based upon the recommendations of the French Ministry of Interior :—

TABLE XII

To withstand Penetration of	Reinforced Concrete.	Mass Concrete.	Brick-work.	Normal Earth.
Normal light bombs up to ¼ cwt. . .	10″	1′ 4″	2′ 6″	9′ 10″
Medium bombs—				
1 cwt. . .	2′ 4″	3′ 3″	4′ 11	16′ 5″
2 cwt. . .	3′ 8″	5′ 7″	8′ 3″	26′ 2″
Heavy bombs—				
6 cwt. . .	4′ 7″	6′ 11″	13′ 1″	39′ 4″
1 ton . . .	6′ 7″	9′ 10″	19′ 8″	65′ 8″

An official Swiss publication [79] contains the following useful information.

TABLE XIII

THEORETICAL DEPTH OF PENETRATION FOR DEMOLITION BOMBS

Weight of Bomb. Kilos.	Concrete, 5,690 lb. at 28 days with special reinforcement.	Reinforced Concrete (3,130 lb. per sq. in. at 28 days).	Rammed Concrete.	Limestone.	Soft Rock.	Hard Core or Compressed Gravel.	Earth. Sandy.	Earth. Stony Clay.
50	0′ 10″	1′ 4″	2′ 0″	1′ 4″	4′ 7″	5′ 7″	8′ 6″	11′ 6″
100	1′ 0″	1′ 4″	2′ 0″	1′ 4″	4′ 11″	6′ 3″	9′ 2″	12′ 6″
300	1′ 6″	2′ 0″	3′ 0″	2′ 0″	7′ 7″	9′ 6″	14′ 1″	19′ 8″

TABLE XIV

THEORETICAL DEPTH AND DIAMETER OF THE SHELL HOLES IN FEET FOR MATERIALS IN WHICH THE BOMB PENETRATES AT LEAST THE WHOLE OF ITS LENGTH (Demolition Bombs)

Weight of the Bombs. Kg.	Soft Rock. Shell hole.		Compressed Gravel. Shell hole.		Sandy Earth. Shell hole.		[illegible] Earth, Clay Earth Shell hole.	
	Depth.	Diam.	Depth.	Diam.	Depth.	Diam.	Depth.	Diam.
50	4′ 7″	14′ 0″	5′ 7″	16′ 5″	8′ 6″	18′ 1″	11′ 6″	19′ 8
100	4′ 11″	19′ 8″	6′ 3″	21′ 4″	9′ 2″	23′ 1″	12′ 6″	26′ 3
300	7′ 7″	27′ 11″	9′ 6″	31′ 2″	14′ 1″	34′ 5″	19′ 8″	39′ 4

TABLE XV

PROTECTION AGAINST PERFORATION AND EXPLOSION

Weight of Bomb	Concrete, 5,600 lbs. at 28 days specially reinforced	Limestone rock or reinforced Concrete ([illegible] lb grade)	Concrete, not reinforced (2,150 lb per sq. in. at 28 days)	Construction as in Tunnel		
				Soft Rock	Compressed Gravel	Earthy Sand
50	2' 4"	4' 1"	4' 7"	11' 6"	18' 1"	21' 4"
100	3' 7"	5' 7"	6' 11"	16' 5"	24' 7"	29' 7"
500	4' 7"	6' 11"	9' 2"	24' 7"	36' 1"	42' 8"

(c) ***Fragmentation and Penetration of Splinters.*** Fragmentation is the distribution of fragments or splinters from the bomb which takes place in all directions when the bomb detonates on the surface in the open. The maximum concentration with respect to the distribution of effective fragments along the axis of the bomb occurs from the zone of the centre section of the bomb and is smaller towards the ends. For all practical purposes it may be taken that fragments are projected at all angles from the horizontal up to 60 degrees.

The momentum acquired by fragments is such as to carry them past the moving gases and they reach a distant target before the blast pressure.

Tests carried out by exploding bombs in a canister submerged under water or in a sandbag enclosure have disclosed the fact that a proportion of the casing is often reduced to dust and remains irrecoverable. The total number of fragments from any ordinary bomb runs into thousands, and although by far the greater percentage may weigh less than 1 oz., they may nevertheless be lethal to human beings and animals. The number of fragments ranges between 2,000 and 6,000 for all sizes of bombs from 25 lb., and the average size of each fragment tends to increase with the weight of the bomb.

The maximum velocities attained by fragments are normally acquired within 10 ft. from the burst of bomb, and may approach as much as 7,000 ft. per sec. The fragment velocity of course diminishes rapidly, due to air resistance at this speed, and at about 50 ft. from the bomb the velocities probably lie between 2,500 and 5,000 ft. per sec., the higher velocities being associated with the larger bombs.[6]

The average range of bomb fragments is about 500 ft., but the maximum range if the bomb is detonated above ground in the open may be as much as seven to ten times this.

If the bomb bursts below ground the gross range may be halved.

Fragment velocity, weight and shape of particles determine the penetrative power of the splinter and the depth to which a given fragment will penetrate different materials may be taken very approximately to vary inversely as the specific gravity of the material in question.

The following approximate formula for the penetration of splinters into wood is given in "Structural Defence":—

$$P = K\frac{MV}{A}$$

P = depth of penetration, in inches.
M = mass of fragment, in ounces.
V = velocity of fragment, in ft. per sec.
A = area of face of fragment presented to the target, in square inches.
K = $1{\cdot}4 \times 10^3$ for Douglas fir.

It will be seen at once that the penetration is a function of the momentum possessed by the fragment and also of the area presented to the target. Thus a long fragment will achieve greater penetration if it strikes the target end-on than broadside on. Indeed, the manner of striking, which is mainly a matter of chance, may determine whether it perforates or merely dents the target.

Actual test results have shown that fragments weighing $\frac{1}{8}$ oz. and striking Douglas fir with a velocity of 2,000 ft. per sec. penetrate about 5 in., whereas fragments weighing 1/200 part of an ounce and striking with a velocity of 2,000 ft. per sec. penetrate 0·8 in.

It would also appear that the amount of penetration into a very soft substance is practically independent of velocity. The volume of material displaced does appear to be proportional to the striking energy, that is to say it is proportional to the square of the velocity, while the rate of destruction of energy near the surface of impact appears to be proportional to the cube of the striking velocity. Greatest damage occurs near the point of entry, the disturbance of the material pene-

trated decreasing as the fragment penetrates more deeply. The effect produced by a bullet is however somewhat different, since the hole at entry is smaller than the cavity produced further in when the bullet appears to deviate from its path and break up.

The Perforation of Metal Plates by Fragments

When bomb fragments attack mild steel plates the percentage of perforations to hits tends to increase with weight of bomb.

The number of hits and consequently the number of perforations for a given area of target decreases rapidly with distance from the bomb. For example, the approximate number of perforations through 100 sq. ft. of mild steel plate 1 in. thick falls from 42 at 30-ft. distance to 24 at 50-ft. distance, and 4½ from 100-ft. distance from a heavy bomb. It would therefore seem that the resistance to perforation by fragments of composite plates of steel bolted together with no intervening air gap is only materially improved if the residual velocity of the fragment is less than 800 ft. per sec. after perforating the first plate. For this reason it is desirable to have the outer plate in any composite construction the heavier of the two. When an air gap is provided between two units of a composite plate a scab can be more easily forced off from the rear of the front plate, thus rendering the perforation of that plate easier, and if the fragment owing to its angle of emergence from the front plate can avoid the scab, perforation of the second or rear plate may be assisted. If the fragments cannot avoid the scab, perforation of the second plate may be hindered.

Summarising: the depth to which a bomb fragment can penetrate structural materials depends on the weight, size and shape of the fragment, its velocity, the angle of strike and the material attacked.

(*d*) (1) *Explosive Force on Impact.* The explosive force on impact concentrates its effort in the direction of least resistance, and in the case of bombing this is usually in an upward direction. The forces in the zone of expansion, though momentary, are of exceptionally high magnitude, and, because of the suction wave effect, are difficult to translate into equivalent static loads.

(*d*) (2) *Explosive Force in an Enclosed Space.* The confining

of an explosion adds greatly to its power, and once the explosive has been "touched off" no known force can prevent its completion. The disruptive effects of tamped explosions are similar to those of concussion charges used in demolitions.

(*d*) (3) *Explosive Forces after Penetration into a Yielding Material.* The effects of the explosion in such cases are similar to those of a buried charge. The maximum and effective radii of destruction may be gauged from the following.

(*d*) (4) *Forces from Explosive on Close Contact.* As already pointed out, the violent forces of a high explosive near the centre of the zone of expansion may be sufficient to cut through heavy steel rails. In the case of gun-cotton the charge must be tightly bound to and in close contact with the material to be cut through and only a few inches' separation may be sufficient to prevent the demolition desired. Thus it may well be in practice that the charge in a bomb will never get sufficiently close to material in the target to develop the maximum disruptive effect and structural units like beams and stanchions will be displaced without actual rupture.

(*e*) *The Transmission of the Wave of Concussion in Solid Material.* The earth tremors accompanying the explosion of H.E. bombs are but one manifestation of the transmitted wave of concussion through solid material from the point of impact. The velocity of propagation depends upon the physical properties of the medium, but observations appear to show that the speed is that of sound.

For example, the concussion wave travels at about 17,000 ft. per second through steel and at about 9,000 ft. per second through concrete. This fact explains the observed disintegration of ordinary reinforced concrete remote from the point of impact of a projectile striking the slab, and the marked improvement obtained when the steel takes a circuitous route through the concrete, as in the case of the special reinforcement shown in Fig. 69.

The magnitude of the earth tremor will, of course, depend upon

1. The weight of the charge.
2. The depth of penetration.
3. The distance from the burst ; and
4. The degree to which the explosion is restrained.

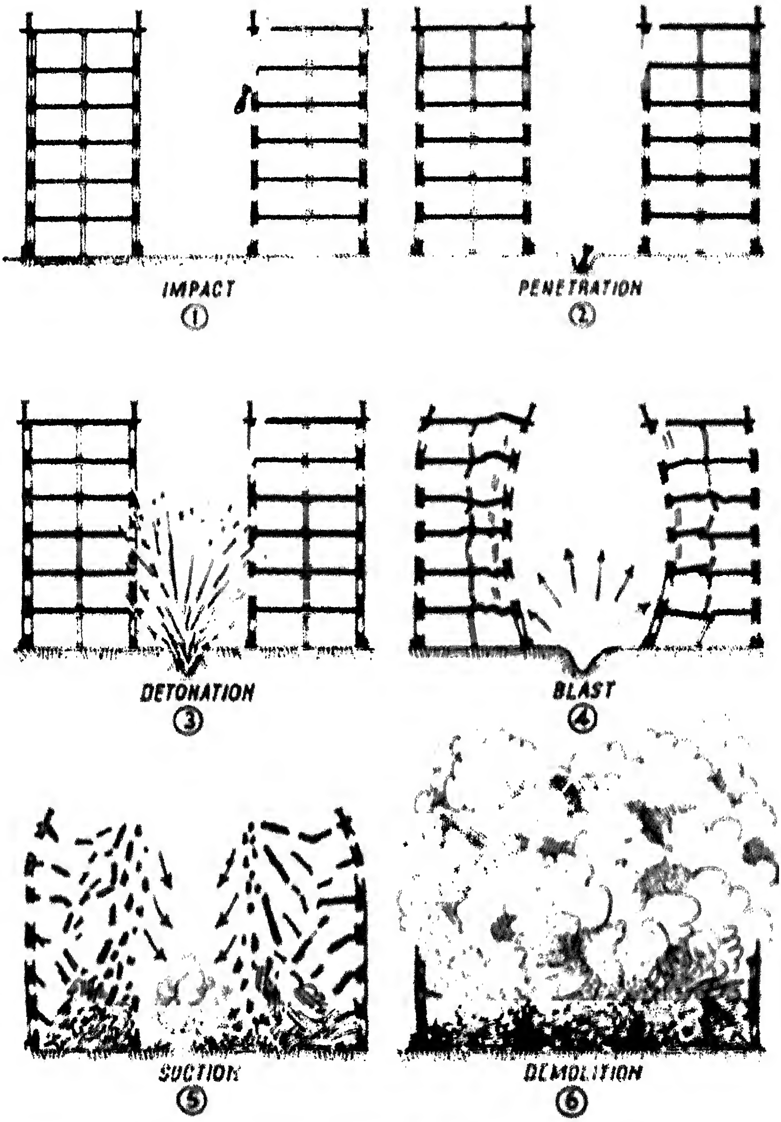


FIG. 10.—Operational sequence of effects of H.E. bomb on buildings as observed in Barcelona.

Methods of dealing with earth tremors due to bombing are discussed in Chapter VII.

The observed effect of a 500 lb. general purpose H.E. bomb falling in a street in Barcelona, 100 ft. wide, with unframed multi-storey buildings on each side, are depicted in operational sequence in Fig. 10.

Blast

Blast is a shock transmitted through the air when an explosion occurs. The hot gases generated by the explosion expand and move outwards at a speed of about 7,000–17,000 miles per hour and push away everything in the neighbourhood with almost incredible force.

Upon explosion $1\frac{1}{4}$ lb. (1 pint) of T.N.T. becomes 15,000 pints of white-hot gas, and temperatures as high as 4,000° C. and pressures up to 150 tons per sq. in. may be generated in a high explosive armour-piercing bomb.

The explosion takes the form of instantaneous combustion of the carbon, hydrogen and oxygen atoms packed solid in intimate contact in the explosive.

High explosives do not easily explode under shock or heat, but require a detonator of mercury fulminate or lead oxide, which is set off by a blow or a spark.

There is no more effective high explosive for military purposes than T.N.T., which was discovered in 1879,[112] and the development of the "atomic" bomb is so remote a possibility that it need not be considered. The development of more powerful explosives than those used in the 1914–18 war is not to be expected.

Detonation

In a high explosive the transformation above referred to is almost instantaneous and is called detonation.

The speed of detonation is of the order of 10,000–25,000 ft. per second, compared with 600–1,000 ft. per second, for an ordinary explosive like gunpowder.

The speed of detonation has a dominating influence upon the localised shattering power of a high explosive, as is exemplified by the case of the use of 1 lb. of guncotton, which,

on detonation, will cut though a steel rail with which it may be in close contact, " whereas no amount of gunpowder will produce the same result." [158]

At the centre of the detonation of a high explosive and for a radius of three times that of the characteristic crater in soft earth the expansion is propagated at the velocity of detonation. Outside this zone of expansion there is a non-translational blast wave which may be transmitted to considerable distances at the approximate speed of sound in air, say, 1,200 ft. per second.

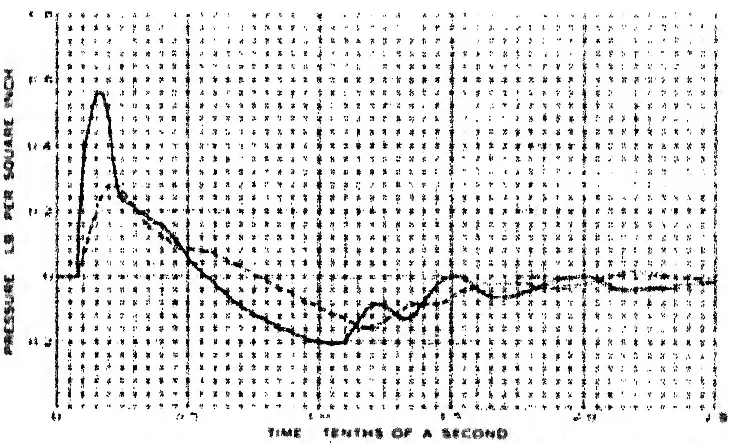


FIG. 11.—Approximate form of blast wave of 1,000 kg. (1 ton) of high explosive at a distance of 500 metres (1,640 ft.) (full line), and 1,000 metres (3,280 ft.) (broken line).

From *Jahresberichte der Chem. Tech. Reichsanstalt* 1922–27 *cit.* Schoszberger, " Bautechnischer Luftschutz," Berlin, 1934.

(Courtesy Inst. C. E.)

The zone of expansion is defined by a radius which may be calculated from the formula $5\sqrt[3]{C}$, where C is the weight of the charge in pounds. Thus a 500 lb. bomb having an explosive charge of 200 lb. may be expected to have a zone of expansion of 29 ft. radius, outside which distance targets would be subjected to blast. Fig. 11 shows the form of the blast wave from the detonation of 1 ton of high explosive 500 metres away and " dotted " the form of the same blast wave at twice this distance from the source.

In each case it will be seen that the peak of high pressure

is immediately followed by a reduced pressure or suction, and that the duration of the wave is the same in each case. It will also be noticed that the intensity of the blast pressure does not fall off in accordance with the law of inverse squares, but that the diminution of pressure with distance apparently follows a linear law. Thus outside the zone of expansion blast may be transmitted considerable distances without material loss of destructive potential. To double the distance outside the zone of expansion no more than halves the pressure ; blast

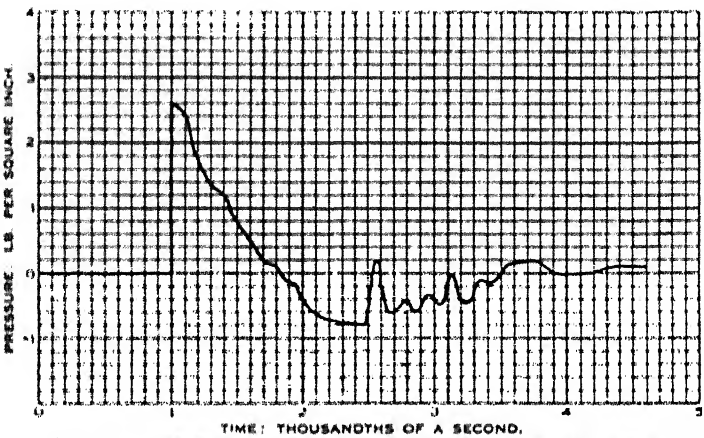


FIG. 12.—Approximate form of blast wave of 0·04 kg. (0·088 lb.) of high explosive at a distance of 6 ft.
From Building Research Station.

(*Courtesy Inst. C.E.*)

pressure is roughly in inverse proportion to the distance from the explosion.

Fig. 12 shows the approximate form of the blast wave in air outside the zone of expansion, and is interesting for comparison with the previous curves in that it shows the same general form, but a shorter duration of the wave. The duration of the blast wave increases with the weight of the charge and the limits which might be expected to obtain in practice may be taken as one-hundredth of a second for the smaller bombs and one-fifth of a second for the heavier.

Blast Wave

Initial phases of blast and suction for 500 lb. medium-case H.E. bomb [5] are given in Table XVI.

TABLE XVI

WAVELENGTH 30 FT.

Distance from Bomb Ft	Max. Pressure, lb per sq. in.	Max. Suction, lb. per sq. in.
30	24·0	3·5
40	10·0	2·0
50	6·0	1·4
60	5·0	1·1
70	4·0	1·0
80	3·2	0·9
90	3·0	0·85
100	2·3	0·8
120	1·7	0·7
140	1·2	0·5
160	1·0	0·4
180	0·7	0·3
200	0·4	0·2

The total duration of positive and negative phases at any distance is 33 milliseconds, the positive phase varying from 8 to 5 milliseconds.

Thus it will be seen that the blast from a 500 lb. H.E. bomb causes an instantaneous increase in atmospheric pressure equivalent to about 30 times that produced by normal wind pressure, say 860 lb. per sq. ft. 50 ft. from the burst.

This, however, lasts for but six-thousandths of a second and the reaction immediately following results in a pull in the opposite direction. Windows in buildings are often drawn outwards due to this effect by the bursting of a bomb in the street.

The Effects of Blast

The positive phase of blast pressure exerts a push on any obstruction ,followed immediately by a pull due to the negative or suction phase.

If the natural period of vibration of the target coincides with that of the blast wave, synchronisation may occur and the target will be subject to an equivalent static pressure

equal to or even greater than the maximum pressure in the blast wave.

The approximate natural frequencies of buildings and structural elements are given in the table below.

TABLE XVII

	Approximate average natural frequencies. Cycles per second.
Buildings, 400 ft. high	1
,, 100 ,,	3
,, 25 ,,	10
4½ in. brick wall panels of normal proportions	20
9 ,, ,, ,, ,, ,,	35
13½ ,, ,, ,, ,, ,,	45
Windows, leaded lights, 30 × 24 in.	25–31
,, 21 oz. pane, 30 × 24 in.	60–70
,, ,, ,, 24 × 24 in.	58

Thus windows, partitions and light structural elements of high natural frequency are likely to be subjected to static pressures comparable with the maximum pressure on the blast wave, and masonry walls and low buildings may synchronise with the blast wave of heavy bombs.

In general, for targets of comparable static strength, those of higher frequency will be more easily ruptured by blast than those of lower frequency.

The blast from a ¼ ton percussion bomb will knock down an ordinary house at 25 yards, and a 1 ton bomb will do the same at 50 yards.[112]

Investigations tend to show, however, that buildings of normal strong construction will not be seriously affected by the blast of 500 lb. high explosive bombs bursting 50 ft. or more away (see Chapters on Shelters).

According to an official Swiss formula the approximate blast pressure at any distance from a high explosive bomb explosion can be calculated as below:

$$P = \frac{248Q}{R^2} \text{ lb. per sq. in.}$$

Table XVIII

Table of Equivalent Static Pressures and Suction on Structures at Various Frequencies of Vibration when Subjected to Blast from a 500 lb. Medium-case H.E. Bomb

Frequency of Vibration of Structural System in Cycles per sec.	Equivalent Static Loads in lb./sq. ft.			
	at 100 ft. Distance		at 50 ft. from Burst	
	Pressure.	Suction.	Pressure.	Suction.
4	0·2	0·2	0·5	0·35
8	0·6	0·6	1·6	1·05
12	1·0	1·0	2·6	1·75
16	1·5	1·5	3·9	2·63
20	2·0	2·0	5·2	3·50
24	2·4	2·4	6·3	4·2
28	2·5	2·6	6·5	4·6
32	2·6	2·8	6·8	4·9
36	2·5	2·9	6·3	5·1
40	2·2	2·92	5·7	5·12
44	2·0	2·95	5·2	5·16
48	1·9	2·92	5·0	5·12
52	2·0	2·9	5·2	5·1
56	2·1	2·85	5·5	5·0

where Q is the weight of explosive in lb. and R is the distance from the explosion in feet. This formula gives a result which agrees reasonably with experimental observation when R is not excessive.

In light doors, windows and partitions the stabilizing effect of the inertia to resist this instantaneous pressure must be neglected, but in heavy massive construction this effect is appreciable.

The effect of the wave of blast pressure on an elastic yielding medium is to impart to it a certain amount of momentum per unit area, which can be expressed as $MV = Pdt$,

where M is the mass of the partition per unit area.

V is the velocity imparted to it.

P is the pressure acting at time t.

The kinetic energy produced in unit area of the partition is $\frac{1}{2}MV^2 = (Pdt)^2 2M$.

The survival of the partition depends upon whether it can absorb the kinetic energy by elastic flexure or by its movement as a whole.

The energy to be absorbed is inversely proportional to the weight of the partition per square foot.

The duration of the pressure pulse is an important factor in the production of shell shock, and authorities agree that a pressure of from 18 to 19 atmospheres is necessary to produce primary shock.

Blast from a nearby burst would blow a man to pieces, but more distant bursts may kill a man by paralysis of the breathing without visible wounds.

INCENDIARY AGENTS

Incendiaries used in warfare may take the form of one of the following :—

A. Spontaneously inflammable materials :

(1) Solids like phosphorus and sodium.

(2) Liquids, such as phosphorus dissolved in carbon bisulphide and zinc ethyl.

B. Metallic oxides such as thermite in its various forms.

C. Combustible oxidising mixtures like magnesium, barium nitrate and linseed oil.

D. Flammable materials such as celluloid, solid oil, resins, pitch, etc.

Spontaneously Inflammable Materials

White phosphorus has the property of igniting spontaneously and burning vigorously when exposed to the air.

Though now primarily a smoke producer, it was much used in early incendiary projectiles and bombs directed upon balloons and light inflammable material. The phosphorus rapidly burnt out with but a low temperature, and this rendered it unsuitable as an incendiary agent against modern more fire-resistant structures.

Timed to burst in the air, phosphorus-filled projectiles rained down burning particles on personnel with considerable effect.

It was used extensively in the World War in small arms ammunition and as tracer bullets for machine guns.

White phosphorus is produced by heating calcium phosphate rock in an electric furnace and by quickly cooling the vapours distilled.

It is a putty-like heavy solid which melts at 111° F. and boils at 549° F. Owing to its chemical activity in air it oxidises with the generation of heat and flame forming phosphorus pentoxide :

$$4P + 5O_2 = 2P_2O_5$$

which, combining with the moisture in the air, forms phosphoric acid :

$$2P_2O_5 + 6H_2O = 4H_3PO_4$$

White phosphorus is the best smoke producer, as 1 lb. of phosphorus makes 3·23 lb. of phosphoric acid.

It must be kept and manipulated entirely under water to prevent spontaneous ignition.

Sodium (Na) was the filling used by the Germans for their largest incendiary shell, 17·5 cm.

It is a soft metal lighter than water. It melts at 208° F. and boils at 1,382° F.

It is obtained by electrolysis of common salt and when brought into contact with water decomposes it on oxidation, liberating hydrogen and generating great heat which ignites the gas. Thus, to be effective as an incendiary sodium requires the presence of water which retards the spread of fire.

Liquids

The ideal liquid incendiary should be spontaneously inflammable on exposure to the air, should have a positive and penetrative effect and be easy to transport and handle.

Various mixtures having the desired properties have been evolved, and perhaps the most effective contains phosphorus carbon disulphide solution which starts the fire, and fuel and tar oils which maintain it.

It is possible that such mixtures might be released by low-flying aircraft with considerable effectiveness.

Metallic Oxides

Commercial thermite is a loose mixture of 23 per cent. of finely divided aluminium and 77 per cent. of granules of magnetic iron oxide.

When ignited the mixture reacts as below producing heat exceedingly rapidly and raising the temperature of the reaction to 3,000° C.[74]

$$8\,Al + 3Fe_3O_4 = 4Al_2O_3 + 9Fe.$$

The iron runs away in a molten state and the slag produced conserves the heat to a considerable extent.

In bombs and projectiles the thermite is in cake form bound with a suitable substance like sodium silicate.

Various proportions of ingredients are used to give quick firing yet delayed consumption.

Oxidising Combustible Mixtures

These contain an inorganic oxidising agent and a combustible substance variously proportioned to comply with the widely differing requirements of incendiary projectiles and bombs.

They are usually intermixed with a suitable binder and compressed into the shell or bomb, the device being provided with a detonating primer which ignites the contents on impact.

For further detailed particulars the reader is referred to "Chemicals in War."[74]

Flammable Materials

The principal uses of these materials are to act as secondary incendiary materials which, carried to the target in the projectile or bomb, prolong the incendiary effect of the primary, which must be spontaneously inflammable.

In incendiary bombs of intensive type the body is divided into two sections, the front portion being filled with thermite and the rear portion with solid oil through the middle of which passes a thermite core.

A nose fuse ignites the thermite on impact and the oil is then melted and ignited by the heat generated.

In the scatter type of bomb, small units of flammable

material saturated with oils, etc., are scattered about the target on impact under the action of a base fuse.

INCENDIARY BOMBS AND THEIR EFFECTS

An incendiary bomb is usually in the form of a small aluminium cylinder filled with thermite, a mixture of aluminium and iron oxide, which burns at a temperature of 3,000° C. (5,432° F.).

The cases of some incendiary bombs are made of elektron, an inflammable alloy of magnesium, aluminium and zinc.

The bomb has a percussion ignition device which sets light to both the contents and casing, which burn vigorously with a dazzling * light for seven to ten minutes.

Bombs of the scatter type have a small explosive charge which throws off six or eight "pups," which burn some distance away from the parent bomb.

Thermite burns independently of a supply of air — the action of burning decomposing the iron oxide, thus liberating molten iron which flows about and spreads the fire to any combustible material in the vicinity.

The burning bomb itself cannot be extinguished by water or any known chemical means and is therefore thought to be the greatest potential danger to a civil community.

The weight of an incendiary bomb may be anything from 1 kilo (2·24 lb.) to 33 kilos (73 lb.), but the kilo incendiary bomb is expected to be the most generally used.

By its employment each bombing machine is capable of starting no less than 100 fires, and were the modern highly developed incendiary available during the Great War the attempt to set fire to London might have had very different results.

An examination of the map of most cities will bring to light the fact that approximately only 17 per cent. of the total area is occupied by buildings, the rest of the space being taken up by gardens, streets and open spaces.

On the other hand, the bomb does not approach in a truly vertical direction, and the area presented to the target is of the order of 20 to 25 per cent. of the total plan area of the city.

* Source intensity about 50,000 candle power.[38]

Table XIX
Heat Chart

Temp. Deg. C.	Colour.	Temp. Deg. F.	Melting Point.	Boiling Point.	Remarks.
6,200	—	11,192			Temperature of the sun.
3,675	—	6,647	Carbon		
3,600	—	6,512	—	—	Electric furnace.
3,000	—	5,432	Tungsten	—	THERMITE BOMB.
2,658	—	4,816	Tantalum	—	
2,533	—	4,591	Osmium	—	
2,500	—	4,532	Magnesia	Iron	Tungsten filament.
2,200	—	3,992	—	—	Oxy-coal gas flame.
2,165	—	3,929	Iridium	—	
2,050	—	3,722	Alumina	Silver	
1,800	Dazzling	3,272	—	—	Electric lamp filament.
1,781	—	3,238	Platinum	—	
1,615	White	2,939	Steel	—	
1,600	—	2,912	Iron	—	
1,520	—	2,768	Nickel	—	
1,407	—	2,565	—	—	Finishing temp. porcelain kiln.
1,400	—	2,552		—	Finishing temp. fire-brick kiln.
1,320	Yellow	2,408	Glass	—	
1,317	—	2,403	Manganese	—	
1,280	—	2,336	—	Magnesium	Finishing temp. pipe kiln.
1,085	Orange	1,985	Copper	—	
1,061	—	1,942	Gold	—	
962	—	1,764	Brass	—	
959	Cherry red	1,760	Silver	—	
750	—	1,382	—	Sodium	
685	—	1,298	Magnesium	—	
648	—	1,198	Aluminium	—	
630	Dark red	1,166	Antimony	—	A bright coal fire.
500	—	932	—	—	"Critical" temp. for structural steel.
445	—	833	—	Sulphur	
415	—	779	Zinc	—	APPROX. RANGE OF FIRES IN BUILDINGS.
357	—	675	—	Mercury	
327	—	621	Lead	—	Timber ignites.
321	—	610	Cadmium	—	
266	—	510	Bismuth	—	Timber chars.
227	—	441	Tin	Naphthalene	Timber scorched.
114	—	237	Sulphur	—	
100	—	212	—	Water	Moisture evaporated.
96	—	205	Sodium	—	
62	—	143	Potassium	—	
44	—	111	Phosphorus	—	
0	—	32	Ice	—	
−39	—	−38	Mercury	—	
−187	—	−304	—	Liquid air	
−265	—	−445	—	—	Lowest temp. recorded.
−273	—	−459	—	—	Absolute zero.

It may therefore be assumed that 20 per cent. of the bombs dropped on a city will hit a building. Assuming that only 50 per cent. of these are effective, each bomber carrying 1,000 1-kilo incendiary bombs could thus cause no fewer than 100 fires.

Some idea of the intense heat generated by the thermite bomb can be judged by considering the heat chart reproduced, p. 61. Even at 2,000° F. the heat glow is incandescent at a bright orange colour and structural steel has long since passed its "critical" temperature, *i.e.*, the temperature at which its ultimate strength falls below its normal working stress. This fact emphasises the need for the construction of buildings in such a way that all load-bearing members are adequately covered with a fire-resisting or insulating material.

The reader is referred to the London County Council By-laws which give safe regulations for fire-resisting construction.

Owing to its heat generating properties, thermite is used for welding steel, but various improvements have been made in the material to render it more suitable to war purposes in bombs.

Sulphur and iron pyrites are sometimes incorporated to obtain a quicker firing mixture.[38]

THE KILO INCENDIARY BOMB

Generally

This bomb is likely to be the most frequently used.

In action the bomb does not explode, and the fumes generated are unpleasant, but not dangerous.

Whilst the igniting compound is burning the bomb gives a dazzling light; burning sparks are thrown off, some 10 ft. distant. These particles can cause burns, and may ignite curtains, bedding or other combustible material. After about a minute, when ignition is complete, the bomb case continues to burn less vigorously and at a lower temperature. The incendiary effect then becomes less intense but more prolonged, and the bomb will burn through an unprotected wooden floor unless dealt with.

Penetration

The penetrating power of an incendiary bomb is usually less than that of a high explosive bomb of the same weight,

the sectional density of the former being approximately ½ lb. per square inch—about a quarter of that of the latter.

The terminal velocity of the bomb when dropped from any height is usually of the order of 400–500 ft. per second.

Normally the bomb would penetrate any ordinary roof of tiles, slates, corrugated iron, asbestos sheeting, etc., but it will be arrested by a reinforced concrete roof if this is at least 5 in. thick.

In the case of ordinary span-roof construction the bomb may be expected to reach the loft floor, which it will probably burn through if no special protection is provided. It may, of course, start a fire in the roof timbers before falling through to the top floor.

Precautions

It is essential that there should be easy access to all roof spaces and that top floors and roof spaces should be cleared of inflammable material as far as possible and made as fire-resisting as circumstances will permit. Woodwork should be treated in any of the ways recommended on p. 67, and suitable to the circumstances. Two inches of sand, or foamed slag, or 3 in. of dried earth spread on the floor will probably prevent the bomb seriously setting fire to the flooring or structural timbers. Sheets of corrugated iron, suitable asbestos sheeting or durasteel sheets can also be used for this purpose.

Action for Dealing with Bomb

There are four sequences of operations :—

1. Preliminary fire extinguishing and cooling down.
2. Controlling the bomb.
3. Removing the bomb.
4. Extinguishing the resulting fire.

Preliminary Fire Extinguishing and Cooling Down

It is inadvisable to approach the bomb until it has been burning for about a minute, after which this can be attempted by crawling along the floor below the level of smoke and fumes.

Any fires started in curtains, bedding, carpet, etc., should first be extinguished by water, preferably sprayed from a hose,

thus minimising the effect and cooling down the room. It is important to note that water should not be sprayed heavily on the bomb itself as the steam generated will cause violent spluttering and scattering of molten metal.

Controlling the Bomb

After the preliminary use of water and the wetting of the floor, it should be possible to approach within 5 or 6 ft. of the burning bomb, and with the aid of a long-handled scoop to cover it with foamed slag, dry sand or slate dust. About 30 lb. of sand, or 15 lb. of foamed slag, should be sufficient to cover and control the bomb provided it is not thrown on to the bomb, but poured on gently with the aid of the scoop to avoid scattering the molten metal.

Removing the Bomb

The bomb thus controlled can then be lifted with the scoop and placed in a container, as described below, and carried out of the building or thrown out of the window to a position where it may safely burn out.

Extinguishing the Resulting Fire

To extinguish any fires that the bomb may have started, ordinary methods may be employed and the use of extincteurs of a portable nature are recommended for convenient individual use when the bomb has been removed.

Container and Appliances

The "Redhill Sand Container" has been specially designed for the purpose of dealing with incendiary bombs. It can be tilted on its side to enable scoopsful of sand easily to be extracted from it, and it is made of material which will hold the molten remains of the bomb without danger of being burnt through. The handle is so positioned that heat from the bomb will not be felt to any great degree on the hand when the charged container is being carried.

A special scoop with a handle in sections, adjustable to various lengths, is provided with the container. One section is fitted with a hoe to assist in drawing the molten metal into the scoop.

Water Appliances

A small hand-operated water pump which can be used from a bucket with about 30 ft. of hose terminating in a $\frac{1}{8}$-in. nozzle is recommended as being more effective than the wasteful bucket of water.

If it is impossible to enter the room except on hands and knees, the use of anything but a line of hose would be difficult. Some special purpose extinguishers are dangerous, if applied to the burning bomb, as poisonous gases might be produced.

Action to be taken when Control and Removal of Bomb are Impracticable

If the bomb is in an inaccessible position, or for any other reason the above recommendations cannot be carried out, two methods are available :—

(*a*) An immediate direct attack may be made on the bomb with water from a hose, using the jet from as far away as possible.

(*b*) The bomb may be allowed to burn while any resultant fires are kept down. If, however, there is danger of the bomb burning through to the floor below, the first method should be resorted to.

It has been previously stated that water should not be sprayed on to the bomb because it causes violent flaming and scattering of molten fragments, but if it cannot be got at and removed it may be better to attack it deliberately with the hose than to allow it to burn unchecked. Water will cause violent spluttering, but the accumulated effect will eventually reduce the intensity of the bomb and check the spread of fire.

A 25 lb. incendiary bomb will penetrate up to 18 in. thickness of reinforced concrete and it will obviously be desirable to use this thickness of construction over important portions of a building such as stair-wells, as shown in Fig. 13.

The intention is to prevent penetration through to the stair-well and to deflect incendiary bombs on to the flat roof of the building where they can safely burn out.

There is little hope of preventing incendiary bombs causing fires, but the public should concentrate upon limiting the spread of the fire by all the recognised methods—extinguishers, water hoses, sand blankets, etc.

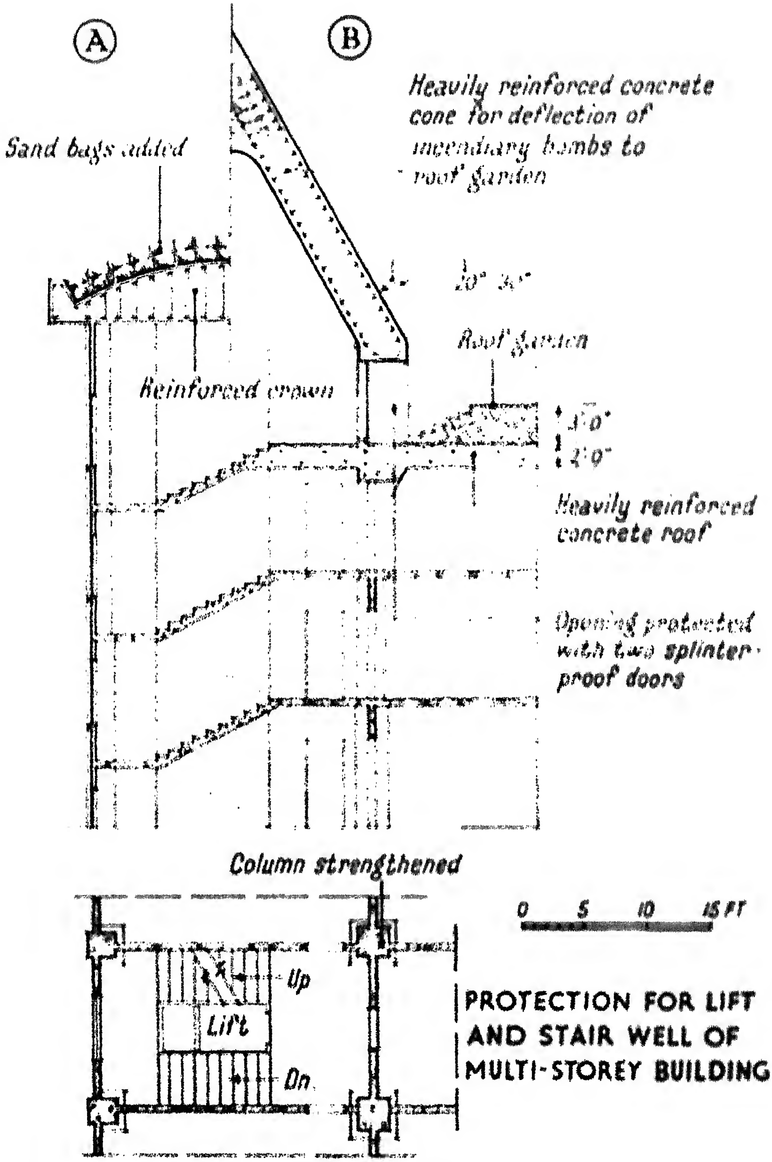


FIG. 13.—The protection of buildings against incendiary bomb.

In A.R.P. Handbook No. 6, dealing with factories and business premises, the Home Office advise that to check incendiary bombs and to limit the spread of the fires which they cause, supplies of silver sand or ordinary dry builder's sand should be provided, preferably in specially prepared containers with long-handled scoops. If an incendiary bomb falls where it cannot safely be allowed to burn out, and it can be approached near enough, as much sand as possible should be thrown over it.

Alternatively it may be possible to pick up the bomb itself in a long-handled scoop or shovel, and remove it to where it can do no harm. On no account should water be thrown on to a burning incendiary bomb, as an explosion may result.

When approaching a burning incendiary bomb it is advisable to wear efficient dark glasses. Those used in acetylene welding will be suitable.

A light asbestos shield will also be useful for protection against the great heat that may be generated.

Fire Protection

Apart from considerations of air attack, the factors influencing the need for fire-resisting construction include exposure-hazard, use, and accessibility to means for fire-fighting.

Exposure-hazard has been classified in the Home Office "Manual of Safety Requirements in Theatres and other Places of Public Entertainment."

A list of trades and occupancies with high fire risk will be found in A.R.P. Department Handbook, No. 9, Appendix C (Ref. No. 161).

The rules of fire-resisting construction issued by the Fire Offices' Committee rest on proportion in fire-hazard and graded standards.

The first and most rigorous standard is divided into sub-standards IA and IB, in the former applying to buildings used as cotton mills, flax mills, paper mills, shirt factories (Ireland), wallpaper factories, woollen mills and worsted mills.

Fire Protection of Timber by Chemicals

Of 160 different chemicals which help to fireproof wood, thirty-three are commonly used and increase ignition temperature by some 200° F.

The treatment takes the form of impregnation with 1–12 lb. per cubic foot.

Among the chemicals used are the following :—

Mon-ammonium phosphate, approved by the L.C.C., and the most satisfactory.
*Ammonium sulphate.
*Ammonium bromide (gives off noxious fumes in a fire)
*Ammonium chloride.
Borax.
Boric acid.
Ammonium arsenates (also insects and fungi).
Zinc chloride.
Aluminium sulphate.
Manganese chloride.
Nickel sulphate.
Calcium acetate.
Oxalic acid.
Sodium bicarbonate.
Sodium silicate.
Sodium chloride.
Sodium sulphate.

I.C.I. products cost 6*d.* to 2*s.* per cubic foot of treated wood. Impregnation with a 20 per cent. solution of mon-ammonium phosphate and subsequent drying costs approximately 3*s.* per cubic foot of treated timber.

Calders' Wolmanising with 12 lb. Wolman salt per cubic foot. Spark-proof only, accepted by L.C.C. as preservative only. Cost, £5 per standard 165 cub. ft.—7½*d.* per cubic foot.

Calders' fully fireproofing new process—not so preservative—9*d.* per cubic foot.

Under the influence of heat these chemicals react with the wood substance, reducing the yield of inflammable gas and increasing the yield of water vapour and solid charcoal.

Fire Protective Paints

In a fire which has become well established no paint coating will afford the degree of protection given by effective treatment

*There salts are hygroscopic and tend to keep the timber moist. They also have a corrosive effect on metals.

by impregnation. Many paints, however, when efficiently applied, so as to give a thick coherent and adherent coating, will retard the spreading of local sources of fire.

Among the best known and most effective paints are those with a base of sodium or potassium silicate. The silicate may be used either alone or with the addition of fillers and pigments, *e.g.*, china clay, whiting or lithopone, but for the purpose of obtaining a thick coating some filler is essential, and not less than two coats should be applied.

Another type of paint of recent introduction consists essentially of calcium sulphate plaster; this is sold in powder form, and for use it is mixed with water to give a paste of brushing consistency. When applied as a thick film this material is reasonably effective.

Either type of paint can be used for the treatment of timber *in situ* and is definitely superior to whitewash and distemper. Moreover, they are reasonable in cost and are easily mixed and applied.

A suitable cheap silicate paint consists of the following:—

Sodium silicate (in the form of syrup) .	112 lb.
Kaolin (china clay)	150 lb.
Water	100 lb.

Its cost is about 1*d*. to 3*d*. per lb., according to quantity.

Coating woodwork with a wash of 2 lb. of slaked lime and 1 oz. of salt with a pint of cold water will delay its catching fire.

A fireproofing paint having superlative properties is sold by Messrs. Universal Floors Ltd., 91 Gower Street, W.C.

Boards of 1 in. deal treated with this fireproof paint will not be burnt through by a kilo incendiary bomb burning upon it for seventy-five seconds, but such a bomb burns through ¼ in. of steel in six seconds. It is equally suitable for the fireproofing of canvas, fibre boards, paper, etc. It is a priming coat supplied in white, stone or grey, and may be covered with oil paints, enamels or cellulose lacquers. In a fire the decorative coats burn off leaving the protective undercoat as the fire-resisting covering. The covering capacity for one thick coat is 35 sq. yards per gallon on rough sawn timber and 40 sq. yards per gallon on prepared surfaces.

The normal forms of covering for pitched roofs, such as slates, tiles and corrugated iron, even though on close wood boarding, are not proof to perforation by the 1 kilo incendiary bomb. Indeed, it seems that the normal effect is for the bomb to lodge on an attic floor and start a roof fire.

DURASTEEL

The 3DF2 FIRE PROTECTION PANEL is an entirely British product, designed for use where great strength and fire resistance are required. It will withstand temperatures up to 1,000° C.

By reason of its compactness and adaptability the 3DF2 sheet proves an economical alternative to brickwork or elaborate air space constructions.

3DF2 panels are widely used for protective partitioning in cases where space is limited.

Description

A composite flat sheet consisting of two steel facing sheets securely keyed by patent process to a highly compressed asbestos composition core. A pressure of over 2 tons to the square inch is used in manufacture (see Fig. 14).

The panel is strong, compact, light and easily fixed. Its fire-resisting capacity is unapproachable by any other material on the market, as shown by the test with Thermite illustrated in Fig. 15.

TABLE XX

Details of Durasteel 3DF2 Panel

Standard Size.	Galvanised per sheet.	Unpainted black per sheet.	Approx. weight per sheet.	Approx. weight per sq. ft.
6' 0" × 2' 6" × [illegible] (nominal)	[illegible]	[illegible]	[illegible]	[illegible]
6' 0" × 2' 6" × [illegible] „	[illegible]	[illegible]	[illegible]	[illegible]
6' 0" × 2' 6" × [illegible] „	[illegible]	[illegible]	[illegible]	[illegible]

8' 0" × 2' 6" Standard size—pro rata.

Cutting to special sizes extra.

Fixing. 3DF2 sheets are easily drilled and bolted to timber or angle iron framing. Sheets may be butt-jointed behind cover strips or brought together against T-iron.

Fire Test on 3DF2 Panel of Durasteel

Three lb. of Thermite iron was placed on the surface of a standard 3DF2 sheet and enclosed by firebrick. It was ignited in the usual manner and allowed to burn out with the fierceness and intensity of flame which characterises this incendiary medium.

Upon examination of the Durasteel sheet there was no sign of it cracking. The top surface of the sheet in contact with the thermite had fused, and there was also some fusing of the asbestos on the surface, but the panel was quite intact, the undersurface being no more than warm immediately after the flames had subsided. The sample 3DF2 panel used for this test was ⅜ in. thick.

A comparative test was carried out on a ¼ in. mild steel plate. In this case an equal quantity of thermite burnt right through the steel in approximately six seconds (see Fig. 15).

N.B.—Thermite is a granular mixture of aluminium and iron oxide, the ingredients of which combine when ignited, attaining the high temperature of 5,400° F. during combustion.

3DF2 Durasteel in its thickest form (⅜ in.), when fixed between roof and ceiling will afford complete protection against the 2 lb. type of incendiary bomb. Where wood rafters are used, the entire timber work should be covered with 3DF2 sheeting ⅛ in. thick, the thicker ⅜ in. sheeting being installed above the ceiling; the object being that when a bomb has penetrated the roof and the thin ⅛ in. sheeting, its velocity will be so reduced that it will then burn out harmlessly on the lower sheeting protecting the ceiling, and the flames will be unable to reach the protected rafters above.

In the case of a new building the most effective method is to use Durasteel CORRUGATED steel-and-asbestos roofing sheets for roof cover, and supplement this by 3DF2 flat sheeting fitted beneath. It should be noted that by reason of its steel core the Durasteel patent roofing sheet is strong, and the corrugations give it an elasticity tending to absorb the blast of explosion. At the same time its asbestos covering gives the Durasteel corrugated sheeting fire-resisting qualities, which render it ideal for use with the special type 3DF2 fire protection sheet.

The incorporation of a special fibrous impact absorbing

sheet in the construction, as shown in Fig. 16, is an advantage.

N.P.L. tensile tests on Durasteel flat sheets show the ultimate stresses to be :—

TABLE XXI

$\frac{3}{8}$ in. thickness	. .	2,980 lb. per sq. in.
$\frac{1}{4}$ in. ,,	. .	3,950 ,, ,, ,,
$\frac{1}{8}$ in. ,,	. .	5,680 ,, ,, ,,

Comparative fire tests by manufacturers gave the following results :—

$\frac{1}{4}$ in. asbestos-cement sheet subjected to flame from oil-fired furnace. Temperature of flame, 970° C.	Sheet exploded in forty seconds. Sheet placed in different position exploded in thirty seconds.
$\frac{1}{4}$ in. flat "3DF2" DURASTEEL fire-protection panel subjected to flame from oil-fired furnace for ten minutes and then quenched whilst hot. (Temperature of flame, 970° C.)	After 3DF2 was subjected to flame for seven minutes the sheet was quite cool at back. After nine minutes very slight cleavage on sides of sheet. Quenched after ten minutes, very little warping.

Impact Test

A steel bar, 3 in. diameter, with a rounded end, $\frac{3}{4}$ in. radius, weighing 44 lb., falling from a height of 25 ft. on to the surface of the sheet caused no cracking or splitting.

"IMPERMITE"

"*Impermite*" is a laminated plywood asbestos cement product suitable for insulation and fire-proofing construction. Supplied by the Gasproofing Co., it has been subjected to the following tests by the manufacturers with the results shown below :—

1. Action of Water

After four days' immersion in cold water, the specimens showed a $3\frac{1}{2}$ per cent. increase in width due to absorption. After an immersion test lasting thirty hours, which included

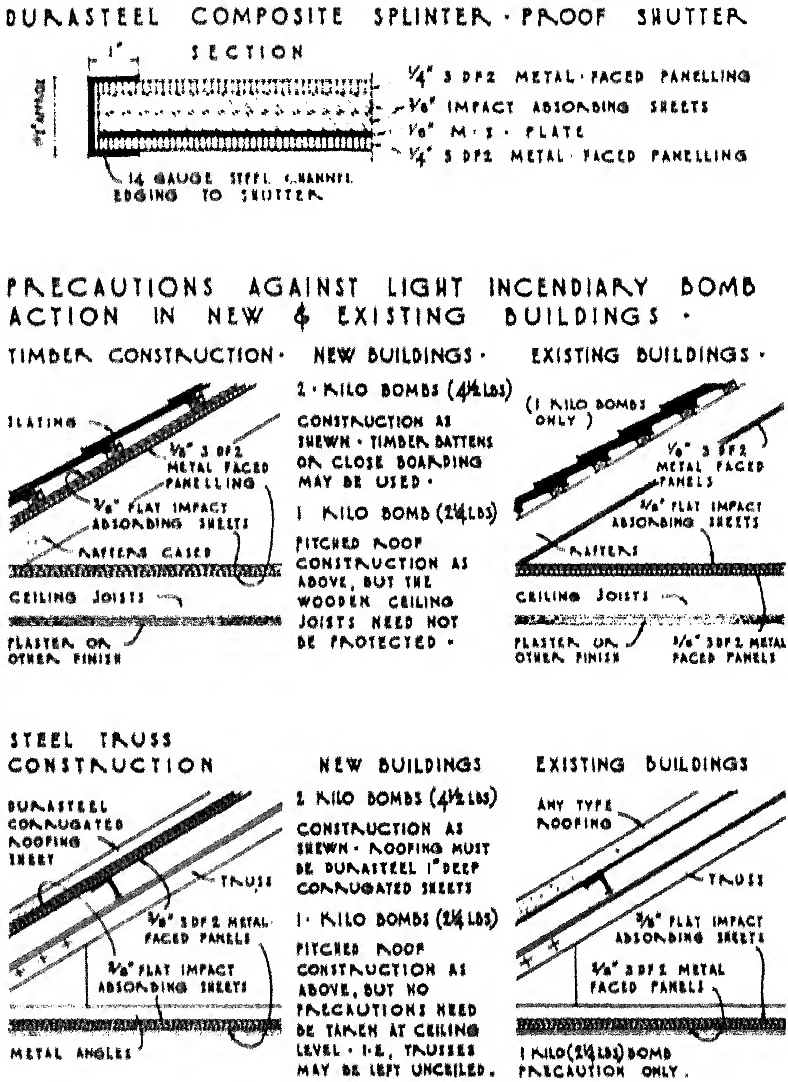


FIG. 16.—The uses of Durasteel in resistance against the incendiary bomb.

two periods of eight hours, when the water was boiling, the average increase of width was $4\frac{1}{2}$ per cent. In neither case was there any sign of warping, nor signs of detachment of the asbestos cement from the wood.

The specimens were dried rapidly after the above tests without producing distortion or any alterations in the asbestos coatings.

2. Action of Fire

Three pound Thermite bombs were ignited on " Impermite " sheets laid on the ground. The asbestos cement surface in contact with the bombs was destroyed, and the wood heavily charred over an area of 6 × 6 in.

In the case of the $\frac{3}{8}$ in. double-sided sheet, the under surface of the " Impermite " was discoloured and slightly fissured.

In the case of the $\frac{5}{8}$ in. double-sided sheet, the lower surface of the sheet was intact and not even discoloured.

3. Acid and Alkali Tests

Hydrochloric and nitric acids have a slight action on the surface-carbonate in the asbestos.

Concentrated sulphuric acid, caustic alkalis, ammonium chloride and sulphate, have no action, nor have benzol, alcohol, etc.

Tests with the above substances lasted for forty-eight hours.

Asbestos Wood

Turnall asbestos wood has established a high reputation for fire resistance, and its heat-insulating properties render it suitable for the covering of floors and roof timbers likely to be subject to the attacks of the incendiary bomb.

Half inch thick asbestos wood material supported on beams at 2 ft. 3 in. c/c easily withstood the impact of a 3 lb. dummy test bomb dropped from a height of 25 ft. with a striking velocity equivalent to that of a kilo incendiary bomb having penetrated a roof. A kilo thermite magnesium bomb burnt out on the test surface without penetration, and the heat generated was not transmitted by the sheet outwards from the seat of the fire to any appreciable extent.

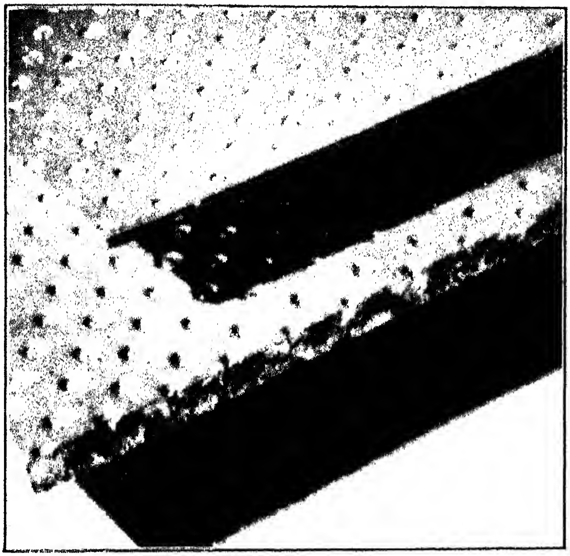


Fig. 14. Photograph showing two sheets of Durasteel [illegible] in. and [illegible] in. thick respectively.

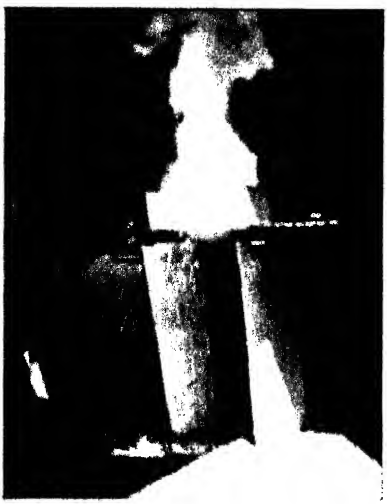


Fig. 15.

4 lb. thermite iron burning on Durasteel (DF2) sheet [illegible] in. thick. Fire burnt itself out but did not penetrate Durasteel (DF2) sheet.

4 lb. thermite iron burning on mild steel plate ¼ in. thick. Shows molten thermite falling through to ground after penetrating sheet in 6 seconds.

To face page 24.

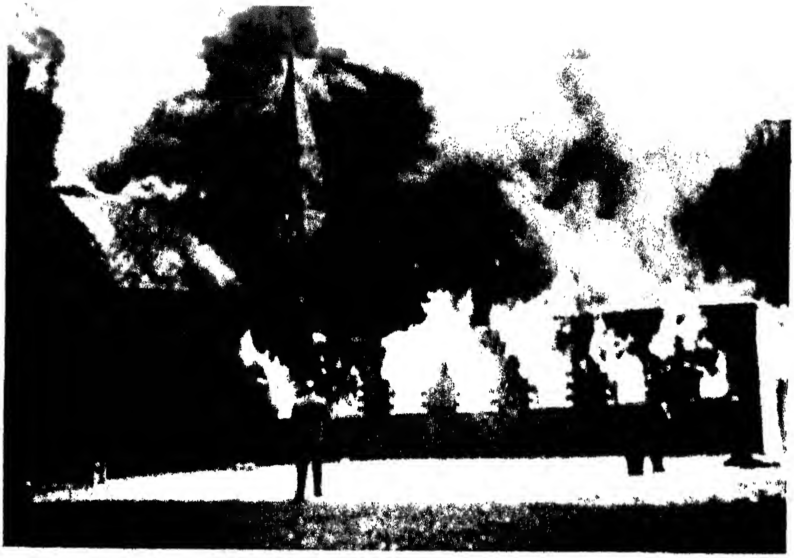


Fig. 17. — Test conflagration

Fig. 18. The anti-fire bomb being thrown into the fire

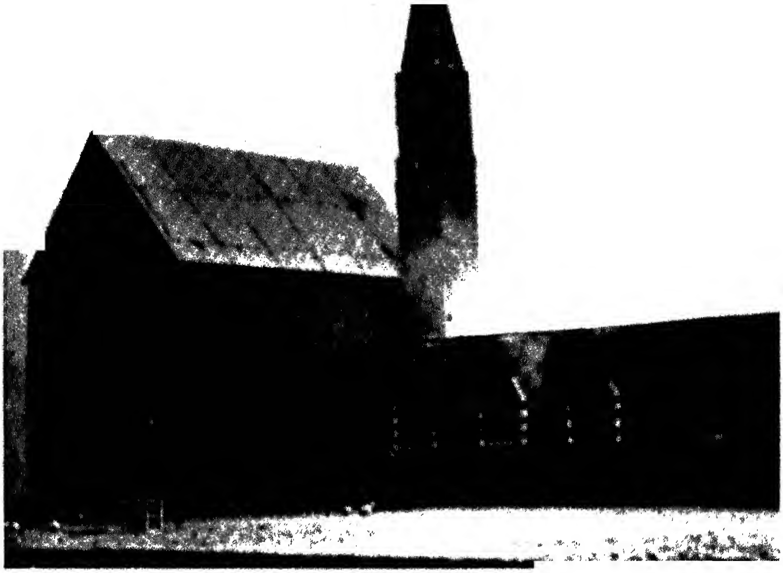


Fig. 19. Photo taken three seconds after throwing anti-fire bomb into conflagration.

Kimoloboard

This is another fire-resisting panelling board sold by Messrs. Cellactite and British Uralite Ltd., Lincoln House, W.C.1. It can be cut with a saw, nailed, planed and generally treated like wood. It is composed of asbestos and diatomaceous earth—ideal materials for fire resistance and thermal insulation respectively.

Tests show that ½ in. thickness of this board safely withstands the burning of a 1 kilo incendiary bomb without penetration or the dangerous transmission of heat.

Fire Fighting Appliances

The use of the stirrup hand-pump with dual jet and spray nozzle in dealing with the incendiary bomb is fully described in A.R.P. Handbook No. 9, to which the close attention of the reader is earnestly directed.

The Sand and Redhill container technique is also fully described in this publication and the equipment required by fire parties is also enumerated.

Permanently installed water, steam or foam sprinklers, as well as drencher systems, are invaluable for the prevention of the spread of fire, but in a bombardment from the air such installations are vulnerable to damage.

Automatic chemical extinguishers, provided they be self-contained and independent of supply pipe lines, are likely to be of more service in dealing with fires caused by bombardment.

Such a device is illustrated in Figs. 17, 18 and 19.

The Self-acting Fire Extinguisher

This anti-fire bomb, originally invented in Italy and widely used both in that country and in France, is available in Great Britain, under the name of the SELFAC automatic extinguisher, from Messrs. Universal Floors Ltd., 91 Gower Street, at 30*s.* each.

Little bigger than a melon, the device is constructed of special waterproof cardboard and contains powders, which under the action of heat decompose into a gas which immediately extinguishes the fiercest fire.

Protruding from one end of the "bomb" is a wooden handle, and at the other a sensitive wick and fuse, which at 275° F. causes the device to burst.

The bomb can extinguish fierce spirit and oil fires, and protects an area of approximately 20 ft. diameter.

It covers the surroundings with a white and harmless dust, which leaves no permanent mark and is not injurious to individuals.

Hung in inaccessible roof spaces, offices, flats and tall buildings otherwise unprotected, the bomb will ensure the automatic and prompt extinguishing of a conflagration.

Exhaustive tests have shown its effectiveness in dealing with fires of petrol, tar, fuel and transformer oil, calcium carbide and ordinary combustible material.

The bomb is also being manufactured and sold in France and Switzerland, Belgium, Hungary and Italy. It has been submitted to severe tests before leading Government and other experts in many countries, proving it always to be a safe, rapid and efficient fire extinguisher.

This type of extinguisher is particularly effective for protecting vehicles, lorries and vessels carrying inflammables, for general use in ships, particularly submarines, for aeroplanes, petrol stations and garages, cinema projection rooms, underground railways, coal mines, military tanks, etc., as well as possessing special advantages for use by untrained users in houses, factories, business premises, and in A.R.P. generally.

Special Characteristics

The bomb is in the nature of a *papier-mâché* container which bursts with sufficient force to scatter an inert powder non-injurious to human or animal life. This powder rapidly and completely asphyxiates the fire.

The fire extinguisher also has the following characteristics :—

1. It contains no liquid or chemical liable to evaporation and is guaranteed to be effective for a period of five years without requiring any attention.

2. No skill or experience is required, there is no mechanism to get out of order or to operate, nothing to adjust, and no need for personal risk in remaining near a fire. It can be used by the aged or the infirm.

3. The metallic part is not projected when coming into action, and therefore cannot cause damage to life or property.

4. The envelope is dampproof and protects the chemical powder completely.

5. Its action is instantaneous and its bursting is harmless both to the user and the surrounding objects.

6. It is always ready for use, the fire itself causing it to act.

7. The spread is in the shape of a sphere having (with the standard type) 18 ft. diameter.

8. The extinguisher, if suspended from ceilings or walls, would be actuated by rise in temperature and extinguish fire in a manner similar to a sprinkler system. It can be introduced into burning rooms or buildings on a pole or thrown or rolled from a distance.

9. The noise created by the bursting is sufficient to act as an alarm signal to those in other parts of a building.

10. It has an equal effect upon liquid combustibles such as petrol, benzol, tar, and upon solid combustibles such as paraffin wax, rubber, cellulose, wood, or calcium carbide.

11. The extinguishing mixture will not damage surfaces or textiles and the powder sprayed on them can be removed by brush or other domestic cleaner without leaving any trace.

12. The powder is harmless to human beings. The extinguisher can be used with perfect safety in confined spaces as it poes not create injurious gases.

TRANSLATION

FRENCH REPUBLIC
PREFECTURE OF POLICE

MUNICIPAL LABORATORY OF CHEMISTRY

2, Quai du Marche-Neuf Paris

Entry No. 6589. Certificate No. 40727.

Experiments carried out at the request of the "Société Française de la Bombe Pyrofuge X," 35, Boulevarde Haussmann, Paris, on Monday, December 16th, 1935, at 10 a.m. at the Barracks of Firemen of Champeret.

These experiments were made with said Pyrofuge X Bombs brought by representatives of the Société, and comprised the following, a programme set out by the Society's Directorate.

We hereby merely register the results obtained.

Programme of Demonstrations

1. Demonstrating the harmlessness of the bomb.

2. Demonstrating the harmlessness of exploding the bomb when in close proximity to another which might be expected to explode in sympathy.

It was demonstrated that when three operators standing 1 metre apart, and the one in the middle having lit his bomb and caused an explosion, he did so without hurting himself or causing the other two bombs to explode.

3. Demonstration covering the placing of the bomb in water at the start, and yet using it at the end of the demonstration.

A Pyrofuge X Bomb submerged in water for 45 minutes, then taken out and lit, caused an explosion exactly similar to bombs which had not been held under water.

4. Extinction of a vertical wall, soaked in tar and petrol.

On a flat vertical surface made of wooden planks there was spread both crude oil and petrol. This was lit and 25 seconds afterwards a bomb was directed on to the fire, which was put out.

5. Extinguishing of tar and petrol puddle.

An elliptical shaped depression in the earth, 2.40 metres long and 1.40 metres wide, was filled with 5 litres of tar and 5 litres of petrol. This mixture having been lit, it was attacked with Pyrofuge X Bombs. It required only two bombs to extinguish the fire.

6. Extinguishing a wooden structure 27 mm. thick, measuring 4 metres by [illegible] metres and reached by a corridor 6 metres in length.

The structure was set on fire with the help of firewood, etc., lit by an " Electron " bomb furnished by the headquarters of the fire brigade. After 7 minutes of being lit and flaring, the fire was attacked by operators holding Pyrofuge bombs at the end of staves, and so penetrating the structure. The fire was put out with two such Bombs Pyrofuge.

Bell's asbestos protective equipment F. 55 and incendiary bomb snuffer in use.

FIG. 21.—Portable Fire Shield of Durasteel

7. Petrol was poured into wood stacked vertically, and the additional petrol fed into it by a rubber tube.

When this was lit, a Pyrofuge X bomb was thrown into the conflagration and the latter put out.

8. On the floor of a cellar 3 metres by 3 metres by 2 metres in dimension there was spread straw, wooden debris and greased rags. This mass was lit and allowed to burn 4½ minutes before being attacked with Bombs Pyrofuge X.

This was extinguished by ONE Bomb Pyrofuge.

PARIS. *December 28th*, 1935.

Fig. 20 shows Bell's asbestos protective clothing and an incendiary bomb snuffer in use. The spread of fire is checked by its use as the bomb burns out safely under it.

Fig. 21 shows a portable fire shield made of 3D.F2 Durasteel panelling. It is of considerable use to factory fire parties or A.R.P. squads. It is ⅛ in. thick, 48 in. by 24 in., with channel steel-bound edges, and weighs approximately 24 lb. Note the narrow observation slit and the webbing arm straps.

Resistance of Materials to Penetration by Incendiary Bombs

(*a*) *By Impact.* The following are the minimum thicknesses of materials recommended by the Home Office for protection against penetration by impact of incendiary bombs of various weights :—

TABLE XXII

Bomb.	Reinforced Concrete.	Sand.	Earth.	Shingle.	Mild Steel Plate.
1 kilo (2¼ lb.)	3½"–4"	About 6"	About 6"	About 6"	½"
2 ,, (4½ ,,)	5"–6"	,, 3′ 6"	,, 5′	—	¾"
5½ ,, (12 ,,)	—	,, 4′ 9"	,, 7′	—	—
10 ,, (22 ,,)	—	,, 6′ 0"	,, 9′	—	1"

(*b*) *By Burning.* The following are the Home Office recommendations, based on tests, for materials for protection against penetration by burning of the 1 kilo magnesium (electron) incendiary bomb :—

TABLE XXIII

Material.	Minimum Layer in inches	Weight per sq. ft. in lbs.	Remarks
Household ash	[illegible]	[illegible]	As efficient as sand and lighter
Slate dust	[illegible]	[illegible]	
Red ash	1	[illegible]	
Boilerhouse ash	[illegible]	[illegible]	
Refuse destructor dust	2	[illegible]	
Brick dust	[illegible]	[illegible]	
Sodium bicarbonate	1	[illegible]	
Kaolin	[illegible]	[illegible]	
Pumice (ground)	[illegible]	[illegible]	
Dry (virgin) earth (sifted)	[illegible]	[illegible]	
Dry sand	[illegible]	[illegible]	
Foamed slag (ground)	2	[illegible]	Has advantages over sand (much lighter)
Powdered chalk			Not recommended—it will react with the bomb
Asbestos sheet / „ wool / „ wall-board (Types which do not fracture under heat)	½		½ in. gives fair protection
Preparations of the plaster type made up mainly of ground rock anhydrite.	½		½ in. gives fair protection
Asphalt (certain types)	½		½ in. gives fair protection

Foamed Slag Concrete

Complete protection against the light incendiary bomb is assured by spreading a layer of lightweight foamed slag concrete over the surface of the roof.

Exhaustive Government tests demonstrate that a 6 in. layer of foamed slag concrete will prevent penetration on impact and will, moreover, allow the incendiary bomb to burn out safely on the roof.

Foamed slag concrete weighs only 30–33 lb. per square foot 6 in. thick, and Foamag lightweight aggregate can be obtained from Messrs. F. McNeill & Co. Ltd., 52 Russell Square, W.C.1, at the price of 36*s.* 3*d.* per ton delivered.

It bulks as below :—

⅜ to ⅛ in.	3·5 cub. yards to the ton.
⅛ to ⅛ in.	3·0 „ „ „
⅛ in. down	2·5 „ „ „

CHAPTER III

GAS BOMBS AND THEIR EFFECTS

"GAS" to the layman holds unknown terrors, but thanks to the advance of science it is no longer the most deadly weapon in the hands of a potential enemy.

The total number of compounds known to chemical science is estimated at nearly half a million, and about a quarter of a million have been carefully studied and their various effects recorded.

Nearly all chemical substances exert some toxic influences, but during the World War about 300,000 substances were investigated with a view to their use in combat.

Of about thirty found suitable for use only twelve were finally adopted, the elimination being due to the stringent technical and tactical requirements imposed.

Only about six compounds were notably successful, and the following extract from statistical summaries is of interest.

125,000 tons of battle gases were used by the seven principal countries engaged in the World War (all theatres), the approximate allocation being as below:—

TABLE XXIV

	Tons.	Lbs. of gas per casualty
Lung injurants . .	100,500	230
Vesicants . . .	12,000	60
Sternutators . .	6,500	650
Lacrimators . .	6,000	0
Total . .	125,000	192 av.

The total gas casualties were 1,296,853, or one for each 192 lb. of gas.

TABLE XXV

Quantity.	Form of Agent.	Casualties.	Rate per Casualty.
5,000,000,000 lb.	High explosive	10,000,000	500 lb.
1,480,000,000 rounds.	Non gas	14,456,435	104 rounds
50,000,000,000 rounds.	Small arms ammunition	10,000,000	5,000 rounds
1,200 tons 9,000,000 rounds	Mustard-gas shell	400,000	60 lb. 22·5 rounds

Mustard-gas shell proved to be twice as effective as the average gas shell and nearly five times as effective as explosive shells.

The mobilised forces engaged in the World War aggregated 68,321,638, 54·7 per cent. of which became casualties. Although gas caused 4·6 per cent. of all battle injuries and 5·7 per cent. of all non-fatal battle injuries, it caused only 1·32 per cent. of all battle deaths.

Gas was therefore over four times as effective in causing non-fatal casualties as in causing battle deaths.

Modern warfare does not take the form of annihilation of the forces in the field so much as the paralysis of the economic resistance of the nations engaged.

Chemical warfare being most effective in producing non-fatal casualties, which are a military liability, is likely therefore to be adopted to an increased extent in future wars. Indeed it is now clear from the plans of the belligerents in the World War that had this continued for another year the campaign in 1919 would have been largely a chemical war.[74]

Among the gassed the sufferings are less severe and of shorter duration than those caused by other battle injuries, and statistics show that on the whole recovery from gas incapacitation occupied about half the duration of hospital treatment required in other cases of wounding.

The ratio of deaths to total casualties in non-gas cases was over twelve times that of the mortality from gas.

Gas warfare is therefore most effective and humane, and must be expected to play an important part in future wars.

It is a common misconception that there are some gases suitable for use in chemical warfare and which are incapable of neutralisation or filtration by any known means.

"Those well qualified to speak on the subject, notably Professor Haldane, have adduced a number of scientific reasons for disbelieving in the existence of such gases, and also in the likelihood of their being produced by future research. The explanation is simple. The number of volatile chemical substances is limited, and of these only a small proportion are poisonous. Those with a small molecular weight are on the whole the most volatile, *i.e.*, go most easily into vapour. *But they are all of relatively simple chemical composition, and the larger majority are already known.* Any fears on this ground are therefore practically negligible. With regard to the substances of high molecular weight, it is certainly possible that some may yet be discovered to give off vapours more poisonous than any known gas to-day. But, on the authority of Professor Haldane, *the charcoal in the ordinary respirator has the property of adsorbing heavy molecules of vapour quite independently of their chemical composition.* And what, it may be asked, of gases like carbon monoxide and hydrogen arsenide which attack and kill without causing odour or irritation? Again the explanation is simple. Such gases may prove fatal if encountered in the laboratory or factory; but in the concentrations required to kill by an attacking force they could not practically be produced in the open." [66]

Gas attacks on a civil population can be rendered practically harmless by the equipment and organisation of the community properly to combat them.

The underlying principles of chemical warfare can be traced to ancient times when "Greek Fire," reputed to be compounded of sulphur, spirits of wine, pitch, salt, olive oil and resin, was used in the eighth century B.C.

In 1811 the systematic use of sulphurous fumes and carbon smoke as an offensive weapon was proposed by Lord Cochrane, but it was not until 1915 in the Great War that noxious and toxic gases were effectively employed as a belligerent weapon.

Brief particulars of gases now used in war are tabulated on p. 84:—

There are two main types of poison gas which might be used, namely:—

(1) Persistent. (2) Non-persistent.

TABLE XXVI

POISONOUS GASES

Substance.	Chemical formula	Date of introduction.	Boiling point, degrees centigrade	Approximate concentration to incapacitate a man in a few seconds owing to lachrymation or coughing.	Approximate concentration which if breathed for more than one or two minutes would cause [illegible]	Gas concentration which will prove fatal if breathed for half an hour [illegible]
LUNG INJURANTS						
Chlorine	Cl_2	1915	[illegible]	1 : [illegible]	1 : [illegible]	[illegible]
Phosgene	$COCl_2$	1915	[illegible]	1 : [illegible]	1 : [illegible]	[illegible]
Trichlor-methyl-chloro-formate	[illegible]	1916	+ 128	1 : [illegible]	1 : [illegible]	[illegible]
Chloropicrin	CCl_3NO_2	1916	+ 112	1 : [illegible]	1 : [illegible] (Cumulative)	[illegible]
LACHRYMATORS (ACTION ON EYES)						
Xylyl bromide	$CH_3C_6H_4CH_2Br$	1915	+ 215	1 : [illegible]		
Ethyl iodo-acetate	$CH_2ICOOC_2H_5$	1916	+ 180	1 : [illegible]	1 : 50,000	
PARALYSANTS (ACTION ON NERVOUS SYSTEM)						
Hydrocyanic acid	HCN	1916	+ 26·5	[illegible]	No cumulative action.	[illegible]
SENSORY IRRITANTS OF EYES, NOSE AND CHEST (STERNUTATORS)						
Diphenyl-chlorarsine	$(C_6H_5)_2AsCl$	1917	+ 383 (M.P. 43)	1 : 10,000,000	1 : 50,000	
Diphenyl-cyanarsine	$(C_6H_5)_2AsCN$	1918	+ 350 (M.P. 31)	1 : 10,000,000	1 : 50,000	[illegible]
Ethyldi-chlorarsine	$C_2H_5AsCl_2$	1918	+ 156	1 : 500,000	1 : 20,000	
VESICANTS (EVAPORATION IS SLOW AND ACTION IS THEREFORE "PERSISTENT")						
Dichlorethyl-sulphide (Mustard gas)	[illegible]	1917	+ 217 (M.P. + 14)	[illegible]	1 : 100,000 (with 60 min. exposure).	[illegible]

Persistent gases usually consist of liquids (*e.g.*, mustard gas) which contaminate the area on which they are released, and may continue to give off vapour for hours, days, or even weeks, if not neutralised.

Non-persistent gases, when released, rapidly mix with the atmosphere and disperse quickly.

War gases must have an injurious effect in low concentrations, must be heavier than air and capable of a wide distribution.

They may be released on civil populations from gas bombs or by spray from aeroplanes in liquid form, or irritant smokes.

Persistent gases of the mustard type are most dangerous when released as spray, as the drops of condensed "gas" may remain unsuspected on objects which may come into contact with the human body.

Gas bombs, like incendiary bombs, do not need to be made strong enough to withstand the shock of discharge from a gun, neither do they need a strong casing to produce disruptive effects on explosion.

About 50 per cent. of the total weight of a bomb of this kind will be gas in a concentrated form with a small explosive charge and detonator to disperse the contents over the surface of the ground or building hit.

These bombs are light metal cylinders containing gas. When they fall the cylinder opens and the gas comes out, generally in liquid form. It will lie about in wet weather for several days, possibly. In dry weather it will evaporate in five or six hours. A gas bomb, 50 lb. in weight, will contaminate an area of about 800 square yards, though the whole of that area will not be badly contaminated. Food which has been exposed to gas vapour must be thrown away as it is not fit for consumption. On the other hand, water which has been exposed to gas vapour can be drunk if it is boiled ; it is then perfectly potable.[47]

The penetrative effect of gas bombs is no more than that of incendiary bombs already given on p. 79, but the gas immediately in the vicinity of a burst will be in a deadly concentration, especially if there is no appreciable wind.

Persistent gases, like mustard gas, will evaporate very slowly in cold weather and may even freeze on the ground, being liberated weeks afterwards when thawed and warmed by the heat of the sun.

The production of a grade of asphalt resistant to mustard gas has been achieved as a result of investigation and research work carried out during the past three years by the Limmer and Trinidad Lake Asphalt Co. in conjunction with the authorities responsible for this class of work. It has been approved for anti-gas constructional purposes, where it can be quickly and completely decontaminated by the usual methods involving the use of aqueous bleach mixtures.

The special grade, registered under the trade name of ANTI-GASPHALT, is applied in exactly the same way as ordinary Lake Asphalt Mastic, and in common with all asphaltic mixtures has the advantage for A.R.P. work over other materials in that it can be rapidly laid on any from of base construction, timber, concrete or existing flooring to provide

a gritless, dustless, resilient and impermeable covering which may be used within an hour of its application.

For specialised roofing purposes it further complies with the requirements of B.S.S. 276, 1933, in respect of non-inflammability and is only combustible at temperatures over 700° F. Heat engendered by thermite or other incendiary bombs (3,500° C. to 4,000° C.) carbonises the surface, but does not penetrate the asphalt or make it permeable to water.

It is advisable to have a tray of sand and calcium chloride at entrance to all trenches, dugouts and shelters, for use in decontaminating footwear before entering. (See Fig. 213.)

Gas bombs may weigh as much as 600 lb. apiece, but normally smaller bombs may be expected to be used for gas bombardment.

Gas and arsenical smokes being heavier than air tend to lie low, and if a gas bomb bursts in a street it will probably pour down areas into basements and cellars.

It is generally assumed that, except when a gas bomb is exploded on top of or in a building, the fourth floor and those above it are normally left free of a poisonous concentration of gas.

With gases having cumulative effects, a long exposure to the weak concentration of dissipated gas in the upper storeys of a building may have serious consequences.

It is possible that the nose irritant gases may be produced from some form of generator contained in a bomb. In this case the cloud will be emitted (for some minutes) from the place at which the bomb has fallen and the distance to which the gas will travel may be somewhat greater than with the other non-persistent gases.

A bomb containing persistent gas, such as mustard gas, will make a large splash of liquid at the place where the bomb dropped and will also cover a considerable area with fine droplets. The degree of contamination and the size of the area affected are dependent upon the size and type of the bomb, the nature of the ground on which it falls, and the strength of the wind. In hard ground penetration will be slight, and the liquid will be more widely distributed over the surrounding area. Again, if the wind is fairly strong, the drops formed by the

shattering of the bomb may be carried down-wind for a considerable distance.

Anyone who is near the place where the bomb falls may be contaminated by the liquid drops or splashes and immediate action, as described hereafter, must be taken to avoid serious injury.

Persons walking over gas-contaminated ground will be liable to contaminate their boots by stepping in liquid or picking up mud containing mustard gas. This danger will persist for a long period (usually some days), unless the area is decontaminated, and during this time the area must be railed off and all movement over it prevented.

A dangerous concentration of mustard gas vapour may also travel down-wind in exactly the same way as a cloud of non-persistent gas, though it will not usually be effective for the same distance. Unless the weather is very cold, the contaminated area will continue to give off vapour until it has been decontaminated and the recognised warning sign must be erected to warn persons of the danger from the vapour.

A bomb filled with tear gas will splash the ground in the same way as one filled with mustard gas. Evaporation of the liquid on the ground will produce a cloud of tear gas which will render a large area intolerable to persons who have no protection for their eyes. This vapour effect will continue for a number of days, or until the area is properly decontaminated.

The chief difference between the use of large and small bombs is that, for the same load, there will be in one case a few well-marked and heavily contaminated areas, and in the other case a large number of centres of contamination which might be more difficult to locate and clear.

Pollution of water in open reservoirs may be caused by the vesicants—mustard gas or Lewisite—or by substances producing arsenical smokes.

In this connection Colonel Garforth, of the British Home Office, has stated :—

" The filter beds of a reservoir will deal adequately with mustard gas. They will also deal with lewisite, except for a small quantity of arsenic which the gas forms in solution. This quantity of arsenic is so small that it would require a very heavy concentration to do any harm, and in the case of an ordinary large reservoir the chances of this happening are

almost negligible. There remains, therefore, only the danger from arsenic from the arsenical smoke gases. This is a theoretical rather than a practical danger, as it would require a large number of such bombs to produce arsenic in sufficient quantity to be dangerous.

"The case of the service reservoir, which is of smaller size and which is without subsequent filter beds, is somewhat different. In this case the target is relatively small, so chances of serious contamination are remote. Mustard gas will sink to the bottom below the level of the outlet, except for very small particles. These are destroyed by hydrolysis, and even if some of these small particles escape through the outlet they would be destroyed in the water mains before reaching the consumer. If a bomb containing lewisite or arsenical smokes fell into a service reservoir (the chances of this are very remote) the water should be tested for arsenic and, if necessary, cleansed chemically."[47]

The poisons from gas bombs are very readily absorbed by foodstuffs which, if badly contaminated, would have to be destroyed.

Methods of protection of food may be summarised as below.

In selecting methods of packing choose the material which gives the best protection.

The following table shows the protective value of different types of packing materials :—

TABLE XXVII

Type of Packing	*Protective Value*
Airtight bottles or sealed tins.	Complete protection against all forms of gas.
Airtight glass or earthenware jars.	Complete protection if cover is of glass, metal, bakelite or similar materials. If covered with grease proof paper will protect completely against vapour and give fair protection against moderate liquid contamination.

TABLE XXVII—*continued*

Type of Packing	*Protective Value*
Sealed wooden barrels (for storage of liquids, *e.g.* wines, beer, etc.).	Complete protection against vapour and moderate amounts of liquid.
Wooden boxes.	If joints are tight, good protection against vapour.
Thick cardboard.	Will absorb liquid gas.
Oilskin. Waxed cartons. Transparent moisture-proof wrapping material with a cellulose acetate base.	Good protection against vapour and liquid.
Greaseproof paper.	Good protection against vapour. Some protection against slight liquid contamination.
Thin cardboard. Ordinary papers.	Limited protection against vapour. No protection against liquid.
Ordinary sacks. Textiles.	No protection against either vapour or liquid.

See that where necessary foodstuffs are covered with a suitable protective material. Every layer of material which may prevent gas coming into contact with the food is of value and "wrapped" foods are preferable to bulk unwrapped provisions.

All store houses must be gas proof—see subsequent chapters.

When gas attack is expected the display or transportation of uncovered foodstuffs must be prohibited and at any time the retention of protective covering is a desirable precaution.

The problem of protecting food in shops and warehouses from the effects of gas is still being investigated. Some kinds of food could be consumed after a gas attack if they were treated in a certain way, and though they might not be very palatable they would not be poisonous. The control of food supplies and distribution is one of the major tasks of the authorities.

General protection against bombardment with poisonous gas bombs consists of personal protection in gas proof shelters and

careful decontamination of the affected area after the dispersion of the gas.

The following chapters give details of recommended methods, but after detection of gas certain personal precautions are immediately necessary.

The presence of gas may be detected in a number of ways :—

(i) by the smell ;
(ii) by immediate irritant effects ;
(iii) by visible signs ;
(iv) by chemical testing.

Most gases hitherto used in warfare have either a distinctive smell or a characteristic irritant effect on the eyes, nose or throat. In many cases also there will be visible indications of gas, such as the presence of a cloud or liquid splashes on the ground.

To a large extent, therefore, reliance can be placed upon the senses, particularly the sense of smell, but chemical tests may be available in addition for the identification of particular gases.

DETECTION OF THE VARIOUS TYPES OF GAS

Detection of Lung Irritant Gases

Lung irritant gases are not difficult to detect as they all have a very characteristic odour. The most important example of these gases, and the one most likely to be encountered, is phosgene. This gas has a pronounced smell of musty hay. At the time this smell is detected, irritation of the breathing passages with possibly some watering of the eyes may be noticed, but should not be waited for. Phosgene forms a thin white cloud when the atmosphere is moist, otherwise it is colourless. It is non-persistent.

Detection of Nose Irritant Gases

Nose irritant gases are practically odourless. The first indication of their presence is likely to be irritation of the nose and throat, sneezing, etc. These gases are non-persistent.

Detection of Tear Gases

Tear gases are easily detected owing to their immediate irritant effect upon the eyes. As many of the tear gases are

persistent, and consist of dark brown liquids, care must be taken not to confuse gases of this group with mustard gas contamination.

Detection of Blister Gas

(i) *Mustard Gas.* The odour of this substance is not powerful, nor are the effects immediate, and consequently persons are likely to under-estimate the danger. Mustard gas, whilst the most difficult gas to detect, can nevertheless be recognised in several ways, namely :—

(*a*) by smell ;
(*b*) by visible signs ;
(*c*) by testing apparatus.

The substance has a faint but characteristic smell suggestive of horseradish, onions, or garlic, but some people cannot smell it except in high concentrations. The presence of mustard gas vapour can readily be detected by a person familiar with its smell provided it is not masked by other odours, but after a short time the sense of smell becomes dulled and low concentrations of the gas may not be detected.

The liquid varies in colour from dark brown to pale straw colour. The gas given off from the liquid is invisible. The liquid, if of the pale colour, is difficult to detect on grass, trees, etc. ; and it appears as a wet patch on dry roads or dry earth. On wet roads or earth it gives a slight iridescent effect, similar to that of paraffin on a wet surface. Detection of the liquid is not easy, but provided the smell is known the presence of the gas should be readily recognised.

(ii) *Lewisite.* This substance differs from mustard gas in having a strong smell, like that of geraniums, and it is noticed at once owing to the irritation caused to the eyes and nose. Detection of lewisite should not therefore be difficult.

CHEMICAL INDICATORS

Indicators have been devised which will assist in the identification of *liquid* blister gas and the subsequent defining of the contaminated area. The basis of these detectors consists of a special coloured yellow paint which turns red on contact with *liquid* blister gas. It is important to note that

the vapour of blister gas does not give any indication on the paint. These detectors consist of two kinds :—

(i) *Detectors, Spray.* These are indicators painted with detector paint. Their purpose is to indicate rapidly the arrival of aircraft spray.

(ii) *Detectors, Ground.* These consist of material painted with detector paint which, when brought into contact with a suspected contaminated surface, will give an indication if free liquid blister gas is present.

Chemical Apparatus

The " gas from bombs " problem has been given prominence in all A.R.P. schemes in and around Paris in a way which has much to commend it. Difficulties have been anticipated and experiences carefully collated and applied. Realising that alarms and detectors must generally be in the open, and that fixed appliances, if near enough to be effective, would themselves be destroyed, portable detection apparatus has now been made part of the equipment of such officials as the mobile police.

The type adopted is the Kling polydetecteur (illustrated in Fig. 22), and supplied in this country by Roycott Protectors Ltd., Grand Buildings, W.C.2.

The apparatus is robust — weighs approximately 20 lb. — and, being portable, can easily be taken to a " bombed area " for gas detection.

Briefly, the main features are as follows :—

1. The apparatus differentiates between two classes of gas :

(*a*) Gases having the property of being easily hydrolysed in the presence of moisture : phosgene, palite, surpalite, etc.

(*b*) Gases whose hydrolysis is retarded except in the presence of some catalyst (*e.g.*, heated platinised porcelain tube) : mustard, other vesicant gases, etc.

2. The apparatus is sensitive to concentration of 5 mg. of disphosgene or chloraceto phenone per cubic metre of air or 10 mg. chloropicrine and mustard per cubic metre of air.

3. The apparatus which is enclosed in a stout metal case operates as follows :—

Air is drawn into the machine by means of a hand operated

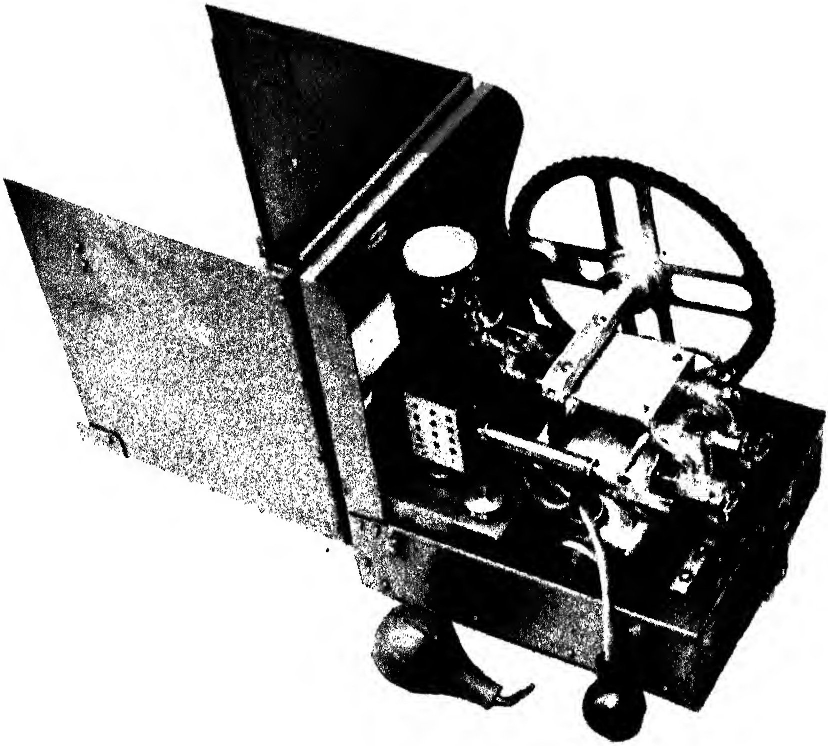


FIG. 22. —View of the Kling polydetecteur for the detection of poison gases.

air pump of robust construction. Air is taken in by two separate inlets, one of which leads directly to one glass detector bulb, and the other, which leads *viâ* a platinised catalyst tube, spirit lamp heated, to a second detector bulb. The two detector bulbs contain bromo phenol liquid indicator, through which the air is bubbled. Also included in the case is a bottle containing a generous supply of fresh indicator with a simple means for transferring the indicator to the detector bulbs. The liquid indicator is normally of a blue colour, which changes to a yellow in the presence of any of the known war gases.

The principle of operation is as follows :—

All known war gases contain one of the halogens (*e.g.*, chlorine, bromine, iodine, etc.). These compounds have the property of being hydrolysed in the presence of moisture. The products of hydrolysis are halogen acids, which have the property of changing the colour of the bromo phenol indicator. With the gases, such as phosgene, lewisite, chlorine, bromine, etc., colour change of the liquid indicator will take place in both detector bulbs. With other gases (mustard K.S.K., B.B.C.) hydrolysis is retarded, except in the presence of the heated platinum catalyst. Consequently, with these gases change of colour of the liquid indicator takes place in one detector bulb only. Hence the instrument serves not only to detect the presence of war gases, but serves also to distinguish between the asphyxiating gases and the more vesicant gases.

Apparatus for Use Inside Shelters

The Kling polydetecteur described above is primarily an outdoor detector, but the Bruere Aero analyser, also supplied by Roycott Protectors Ltd., is specially suitable for use inside shelters. It is used by the Paris authorities for gas detection in all their first-aid posts.

This detector is illustrated in Fig. 23.

Utilising simple and characteristic chemical reactions, it is claimed to be reliable and not subject to failure or accidental irregularities. It reveals without ambiguity the poisonous products diffused in the atmosphere, such as chloropicrine, chlorine, phosgene, yperite or lewisite, adamsite, hydrocyanic acid, carbon monoxide, etc. It performs :—

1. The analysis of the exterior atmosphere surrounding an

air raid shelter at different heights by means of a fixed analysing device provided with *an aspirator* and "explorer."

2. The control of the air circulated inside the shelter, after having passed through the filters.

3. The control of anything which may have become contaminated by projection, or by passing through dangerous atmosphere (the clothes of persons entering the shelter, the walls of buildings, provisions, containers, etc.) by means of the "explorer" (a simple instrument consisting of a wooden rod with a carrier sponge at one end in which a liquid reagent is placed). On touching anything contaminated with this end

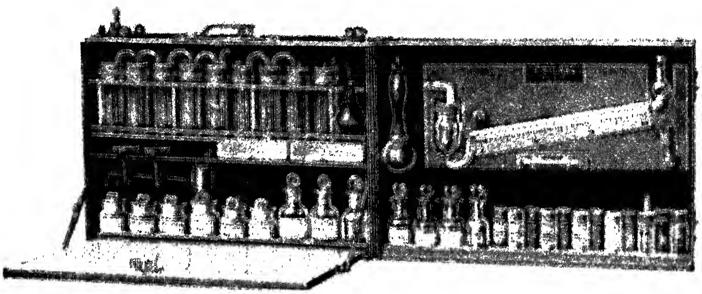


FIG. 23.—Bruere Aero analyser for gas detection.

of the rod the reagent at once discloses the presence of dangerous matter.

4. The apparatus contains a manometric indicator of air pressure, which shows at any moment whether the filtering devices are working normally and whether the shelter is airtight, and also shows losses which occur in air locks.

The Bruere Aero analyser is contained in a metal box about 12 × 17 × 5 in., with all the reagents, absorbing agents and accessories of the fixed station, and also the "explorer."

An aspirator device, which varies according to the conditions of the installation, causes the air, liable to be polluted, to circulate in a series of analysing tubes containing special reagents or reagent papers, any alteration in the appearance of which (change in colour or turbidity) is a sure indication of the presence and the nature of the toxic products employed.

A small folding shelf is provided for the preparation of unstable reagents and the filling of the analysing tubes.

In case of positive or doubtful reactions, the hand detector "explorer" should be used for controlling the air distribution pipe terminals and to give warning of the failure of the filters (which may necessitate the reduction of speed of the passage of the air through the filters, and even sometimes complete stoppage and the adoption of the closed circuit respirable air device).

Reagents and Chemical Products

The reagent papers and ampoules containing the reagents for papers to be impregnated extemporaneously, the compressed tablets for the "explorer" are placed in well-closed aluminium tubes.

Reagent paper No. 1 . .	Detects	The acids, phosgene, hydrolysed yperite and lewisite (alert reaction).
Reagent paper No. 2 . .	Detects	Hydrocyanic acid (specific).
Reagent paper No. 3 . .	Detects	Chlorine and various halogens.
Reagent paper No. 4 . .	Detects	Phosgene (specific).
Reagent paper No. 5 . .	Detects	Sulphuretted hydrogen.
Reagent paper No. 6 (which must be prepared extemporaneously with the ampoules of reagents in the apparatus)	Detects	Carbon monoxide.
Reagent paper No. 7 . .	Detects	Arsines (after the reaction which takes place in a special tube).
Reagent paper No. 8 (is prepared extemporaneously with the ampoules in the apparatus)	Detects	Chloropicrine.
Reagent paper No. 9 (is prepared extemporaneously with the ampoules in the apparatus)	Detects	Yperite.

The Bruere Aero-analyser also contains in wide-necked bottles absorbent or reagent powders, especially a powder for the detection of yperite and lewisite and various reagents.

Gas Detector Service

A special service of chemists trained in gas detection has now been set up in this country.

Decontamination

The cleansing of houses, roads, etc., which have become contaminated with gas will normally be carried out by decontamination squads, the first-aid services dealing with the cleansing of personnel.

Contamination signifies the presence on the ground or any object or person of a chemical substance capable of giving off a poison gas.

It may be encountered as a result of

A. Fine spray from aircraft ;

B. Heavy spray from low-flying aircraft ;

or C. Heavy local contamination from gas bombs.

Decontamination means the treatment of the contaminated ground or object in such a way that danger from direct contact has been eliminated and poisonous vapour can no longer be given off.

The particular treatment necessary will depend upon the identification of the gas, the severity of the contamination and the urgency of decontamination.

The general principles are set out briefly below.

Dealing with the Non-persistent Gases

Ventilate contaminated spaces with fresh air, fan gas out of confined space or light a fire to dissipate the toxic substances.

Dealing with Persistent Tear Gases

1. Cover the liquid with fresh earth.
2. Hose down the area to wash away gas.
3. Treat contaminated material with neutralising chemicals.
4. Rail off affected area until decontaminated.

Dealing with Persistent Blister Gas

(*a*) Neutralise with chemicals.

(*b*) Wash contaminated article with water or a solvent.

(*c*) Cover gas with protective layer of harmless material.

(*d*) Allow weathering effect to destroy the gas if area can be isolated.

Effective methods of decontamination may be summarised as below :—

Note. Bleach paste consists of 4 lb. of bleaching powder to 1 gallon of water freshly made.

Bleach cream consists of 2 lb. of bleaching powder to 1 gallon of water freshly made.

TABLE XXVIII

SUMMARISED METHODS OF DECONTAMINATION

ROAD SURFACES—	*Treatment*
Fine spray on any surface .	Hose down within 30 minutes or leave to weather.
Heavy spray or outer zone of bomb contamination on all surfaces.	Hose down immediately for 10 minutes. Brush down pavements with bleaching powder and water.
Gross contamination round bomb craters on—	
Stone setts, stone paving and concrete surfaces.	Brush bleach cream and water over surface and into joints, leave for 15 minutes and hose down thoroughly.
Wood paving . . .	Hose down for 15 minutes. Leave bleach and sand in contact for 2 hours. Clean off and hose down.
Tar macadam, bitumen or asphalt.	Hose for 15 minutes. Use dry bleach. Road-heating machines may be necessary.
Water-bound macadam .	Leave to weather. Cover grossly contaminated area with sprinkling of bleach powder. Leave 15 minutes and hose down.
Natural earth, grass, etc. .	Cover with 3 in. of fresh earth and leave to weather. If contamination severe and near premises add 25 per cent. of bleaching powder to top layer of earth.
BUILDINGS—	
Stone or brickwork . .	Hose down immediately. Brush in bleach cream. Leave in contact 24 hours. Hose down.
Tile or concrete floors . .	Hose down, leave bleach cream in contact 10 hours. Hose down and apply sodium silicate solution P84 grade diluted 5—1.
Glazed tiles . . .	Hose down and leave bleach cream in joints 10 hours. Hose down.
Distempered walls . .	Wash off with bleach cream, leave in contact 48 hours. Wash off and apply sodium silicate as above.
Papered walls . . .	Strip paper and treat as last item.
Painted surfaces . . .	As for distempered walls.
Wood floors and unpainted woodwork.	Absorb liquid gas with dry earth, which burn. Scrub with bleach cream. Leave for 24 hours. Wash off and repeat. Remove and burn all boards soaked with liquid gas.
Hardwood polished surfaces.	Swab with paraffin. Treat with bleach paste and vaseline. Leave in contact 24 hours. Wipe off and wash.
Upholstery	Strip off and burn.
Bedding and clothing . .	*Woollen :* Treat in steam disinfector for 1 hour. *Cotton :* boil for 1 hour. *Mattresses :* Treat in steam disinfector.
Carpets	(*a*) Boil for 2 hours. (*b*) Weather for 14 days. (*c*) Spray with soda solution and weather 1 week. (*d*) Burn if badly contaminated.

TABLE XXVIII—*continued*

BUILDINGS	*Treatment*
Linoleum . . .	Burn if worn and contaminated, otherwise use bleach cream and wash off
Metalwork . . .	Swab with paraffin or petrol and rub dry
China and glass . .	Treat in bleach solution and wash in hot water
Rubber protective clothing	Hose off, apply bleach cream and wash. Boil rubber boots 2 hours
Respirators . .	Dismantle, boil rubber parts 2 hours. Treat eyepieces and outside of container with bleach cream and vaseline for 10 minutes. Boil haversack ½ hour
VEHICLES—	
Commercial vehicles, buses and trams.	Hose down with bleach cream and water. Leave in contact 1 hour, wash off. Swab metal with paraffin. Leave to weather 24 hours. Remove and burn contaminated upholstery
	Two men working 4 hours per vehicle use 7 lb. bleach and 1 gallon paraffin
Private cars . . .	Hose down with weak bleach. Swab with paraffin. Remove and burn contaminated fabric or upholstery
	One man working 3 hours uses 4 lb. bleach and 1 pint of paraffin per car
PERSONNEL	Remove and dispose of contaminated clothing, strip and wash the whole with soap and water. Bleach paste and vaseline may be used to neutralise known contamination. Wash off in 5 minutes
	Vigorous cleansing in copious supplies of warm water with the utmost promptitude is essential.

Action Advised

The Home Office advise the observance of the following rules :—

(i) Immediately on hearing an air raid warning, take cover in a gas protected room or shelter, unless your public duty compels you to go out of doors or remain at work in an unprotected place.

(ii) Be sure you have your respirator handy in your room or shelter.

(iii) Do not come out of the room or shelter without cautiously trying to discover whether gas is about. The local gas warning will give indication of definite danger.

(iv) If your duty prevents your taking cover during a raid, always have your respirator ready to put on at once, and your protective clothing if necessary.

The tests described in Appendix II show the protection afforded by ordinary buildings not gas-proofed, and Professor Haldane estimates that at least ten times as much gas is needed to poison people in houses as to poison them out of doors.[112]

CHAPTER IV

GAS-PROOF ROOMS

Generally

The public may justly rely upon the authorities to do all in their power to protect them against the dangers of attack from the air, but there are precautions which each householder is expected to undertake for himself, namely, to make one cellar or room in his house into a gas proof refuge, which would be used only during an air raid.

It may at once be said that now the civilian gas mask is issued and maintained the precautions outlined in this chapter need not at once be put into effect.

Appropriate prior arrangements should, however, be made so as to enable the refuge or shelter to be gas proofed quickly under threat of attack.

Selection of Refuge

1. All refuges should be splinter-proof and blast-proof, as well as gas-proof, and where possible an effort should be made to select a refuge, the walls and roof of which approximate to those described on p. 38 as affording reasonable protection.

2. A cellar or basement is best, always provided that there is no risk of flooding and that alternative means of exit exist.

3. If there is no basement, choose a room on the ground floor.

4. Where the walls, etc., of a shelter above ground level are not of the necessary thickness, they should be reinforced, *e.g.*, by sandbags or wooden boxes filled with earth to a height of about 5 ft. above internal floor level.

5. Windows and doors should be protected by the construction of traverses of material of the necessary thickness.

6. The roof of a shelter below ground level or on the ground or first floor should be strong enough to withstand *débris* falling on top of it. If it is not strong enough it should be shored up.

7. The windows of the rooms should be small and, if possible, not in an exposed position. If they face soft ground, the blast of an exploding bomb may be more smothered than if they face a paved or metalled surface. The glass will in any case be liable to be broken by the explosion of high explosive bombs, even at a considerable distance, and some other covering will have to be fastened over the window frame.

8. Where possible, the room should be on the side of the house least exposed to the prevailing wind. Wind pressure will assist the entry of gas through small crevices and ill-fitting window frames.

9. The entry of gas into a house is always assisted by draughts, so it is important to shut ALL doors and windows throughout the house before withdrawing to the gas-protected room.

10. Apply the general gas-protection instructions to the whole house so far as possible after paying special attention to the selected rooms. If the penetration of gas into the house is reduced to a minimum, the occupants of the protected room will be all the safer, and a great deal of trouble will be avoided because the house will not subsequently need airing to the same extent as if gas had penetrated freely into the interior.

Size of Refuge

Unventilated Refuge

The A.R.P. Department of the Home Office state in A.R.P. Handbook, No. 1 :—

"The number of people who can safely remain in unventilated rooms for any prolonged period is naturally limited. If a room contains too many people, the first trouble will not be shortage of oxygen or increase of carbon dioxide, but intolerable discomfort due to rise in temperature and humidity of the air. The capacity of a room is therefore to be measured, not by its cubic content of air, but by the surface area available for the removal of heat, and the condensation of moisture.

"Under English summer conditions, closed rooms may safely be occupied for periods up to 12 hours if the surface area of the walls, floor and ceiling is equivalent to an allowance of 100 sq. ft. per person. The following are examples of how this formula works out in typical rooms :—

TABLE XXIX

Size of Room.	Permissible Occupants.
10 × 10 × 8 ft.	5
15 × 10 × 8 ft.	7
20 × 15 × 10 ft.	13
30 × 15 × 12 ft.	20

"Note that these calculations are NOT based on cubic capacity, which would give different figures."

Note. The figures given above work out to the average cubic capacity allowance of 0·29 cub. ft. per person per minute.

In A.R.P. Handbook No. 6 the following is recommended :—

"To determine the number of people who can be accommodated in a gas proof shelter which is unventilated, allow 75 sq. ft. of surface area (floor, ceiling and walls) per person. On this basis shelters may be occupied for periods up to a maximum of six hours."

Note. This would show a slightly more generous cubic capacity allowance of an average of 0·43 cub. ft. per person per minute.

A man at rest inhales 8 litres of air per minute, and, when actively exerting himself, this rate of respiration is greatly increased.

An American authority [74] has stated that in an unventilated shelter a minimum allowance of 1 cub. ft. per man per minute should be made. This is also the approximate allowance recommended by a French expert, M. Charles Janbert.

German authorities allow four times the A.R.P. Department minimum allowance, nearly 1¼ cub. ft. per man per minute.

In unventilated shelters made gas proof the air soon becomes saturated with moisture and the period required to attain saturation depends largely upon the humidity of the air in the shelter just prior to occupation.

Tests [38] have also shown that after seven hours' occupation in a gas-proof shelter proportioned in accordance with the minimum figures given above, the proportion of carbon dioxide in the air increased steadily up to 3 per cent., and that after twelve hours the concentration of CO_2 would have been dangerous.

Gas shelters are also likely to be overcrowded in an emergency, due to the last minute admission of additional persons seeking shelter. It is therefore of utmost importance to design shelters on a generous scale to make allowance for this tendency and to provide a good margin of safety in the capacity and "survival" time. (See later section on Ventilation of Shelters.)

It should be noted that instead of basing the capacity of closed unventilated shelters on the interior surface area available for the condensation of moisture and the dissipation of heat, the French authorities have a formula based upon cubic capacity:

$$T = \frac{3V}{140N}$$

where T is the time in hours that the closed unventilated shelter can be occupied safely.

V is the cubic capacity in cubic feet and N is the number of persons.

Taking three hours' occupation as normally sufficient to cover the period of a raid the capacity required per person for this period of occupation works out to 140 cub. ft. by this formula, or 0·8 cub. ft. per person per minute.

Gas-proofing

Whilst it is true to say that the methods of making a room gas-proof are fairly simple and their application is largely a matter of the exercise of common sense, yet, as will be shown, thoroughness is essential in carrying out the work.

Under the action of strong external wind air may enter and leave a "gas-proof" room of normal construction at a rate equivalent to four complete changes of the enclosed air each hour unless very special precautions are taken to prevent it.

The object is to seal up cracks and crevices through which gas may find entrance into the room, and the protection will be increased if doors and windows are kept closed throughout the building so as to avoid draughts.

Floors

Floors of basements or shelters on the base concrete and in an unbroken state monolithic with it are not likely to give trouble due to gas leaks, but if any porosity is suspected the surface should be sealed with a cement wash after all cracks have been carefully pointed up.

Floors of timber built on joists are usually ventilated underneath, and are therefore a potential source of danger.

All carpets and linoleum should be taken up and cracks

between and at the ends of boards should be caulked solidly with a mush of newspaper beaten to a pulp in hot water—all such joints being finished off with strips of strong gummed paper stuck down. Linoleum should be replaced and preferably struck down with a strong adhesive, all joints, however small, being filled with mastic and covered with gummed paper stuck down. Spaces round floor and skirting should also be caulked tight with paper pulp and covered over with a wide strip of strong paper stuck solidly down. Carpets should be replaced, taking care not to open any of the joints just made good.

In designing new shelters jointless floors which can be reinforced should preferably be used with a cove skirting carried 3 in. up the wall. Floors of this nature can be added to existing faulty floor surfaces of all kinds and afford a ready means of providing a clean hygienic and gas proof surface. Jointless rubber compounds are also excellent for this purpose, as they are resilient and compliant and therefore not likely to develop cracks under vibration during a bombardment.

Structural requirements are dealt with in Chapter II.

Special attention should be given to the following :—

1. Fill up and cover over joint between floor and hearth.

2. Caulk round all pipes, conduits, etc., carried through the floor and make permanently good with putty, cement or bituminous mastic.

3. Block up all air gratings under floor with permanent plugging arrangements which will not easily blow out.

4. Plaster of paris can be run into cracks too small to be caulked with paper pulp.

5. A thick coat of varnish over the floor and over the "patches" will improve the gas tightness.

6. Watch the gas-proofing of floors to detect destruction by mice and rats and repair immediately.

Ceilings

Ceilings of shelters in existing buildings can be gas-proofed in the following manner :—

(*a*) Loose and porous plaster can be cut away and renewed.

(*b*) Cracks in ceiling plaster can be made good with plasterer's putty and the whole ceiling lined with two strong layers of

lining paper. Alternatively, the cracks can be covered with gummed paper.

(*c*) If the upper side of the ceiling plaster is accessible through the floor or in the loft above, the thickness of the plaster can be increased by the addition of gypsum plaster to the ceiling on top of the laths and between ceiling joists.

(*d*) If not already protected by a floor, the ceiling plaster should be protected by covering the joists with galvanised corrugated iron covered with 2 in. of sand or 3 in. of fine earth. (The ceiling might need an additional central support, see Figs. 24 and 25.)

(*e*) The gas-proofing of the ceiling can be improved by the application of varnish to the lining paper.

(*f*) New ceilings constructed of metal-faced plywood or fibre board with caulked and sealed joints and nail holes afford less danger from vibration and are most gas-proof.

Walls

Underground shelters will normally have gas-proof walls, especially if galvanised iron revetment or concrete wall lining is used.

Shelters above ground level require special attention in gas-proofing the walls. Most normal building construction is far from airtight, and even unbroken wall spaces "breathe" considerably.

TABLE XXX

INFILTRATION THROUGH WALLS MAY BE TAKEN IN PRACTICE TO BE APPROXIMATELY AS GIVEN BELOW.

Wind velocity, m.p.h., or Component thereof normal to the wall surface.	Leakage in cubic feet per square foot of wall per hour.					
	9-in. brick wall.			13½-in. brick wall.		
	Unrendered and unplastered.	Plastered.	Plastered and rendered.	Not plastered or rendered	Plastered.	Plastered and rendered.
5	1·7	0·01	Negligible	1·4	0·005	Negligible
10	4·1	0·03	,,	3·8	0·01	,,
15	7·7	0·06	,,	7·4	0·02	,,
20	12·0	0·10	,,	11·5	0·04	,,
25	18·3	0·15	,,	16·0	0·06	,,
30	22·6	0·22	,,	20·0	0·09	,,
40	34·5	0·41	,,	30·0	0·12	,,

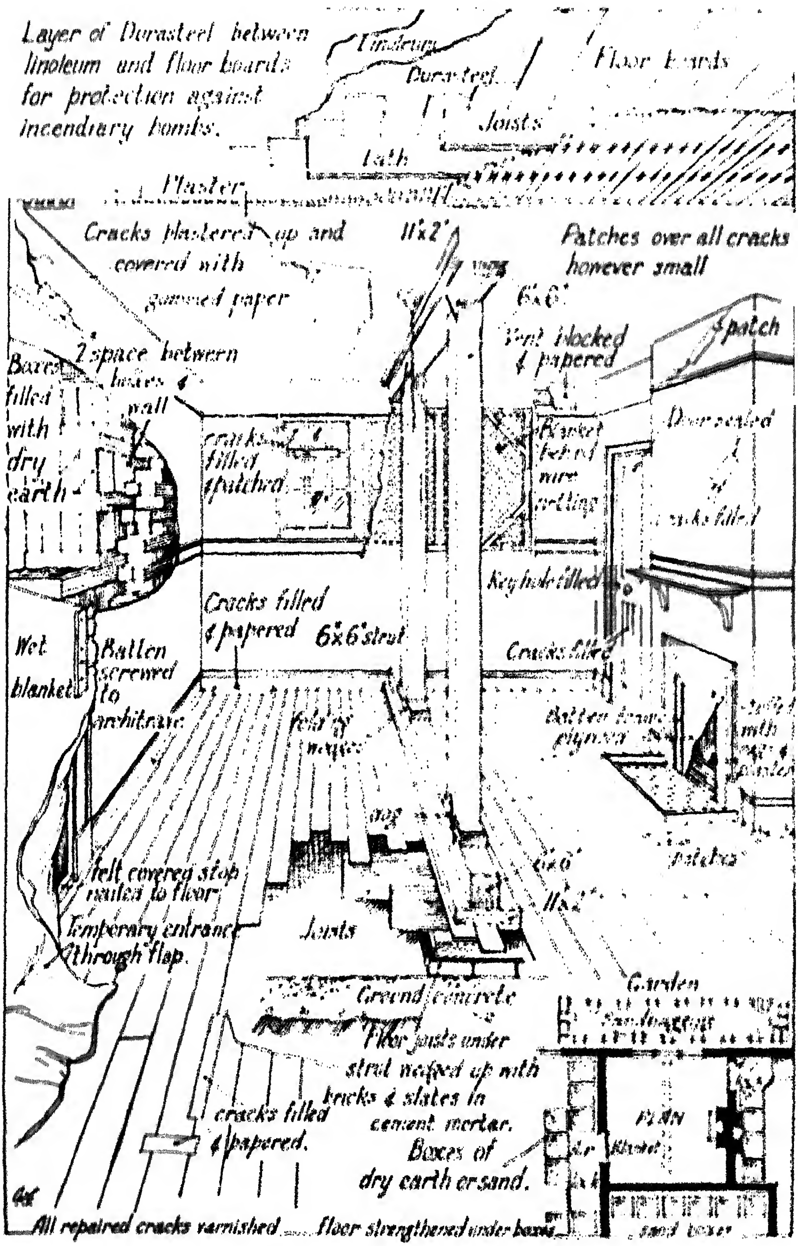


FIG 24.—Preparation of the gas-proof refuge in the average suburban villa.

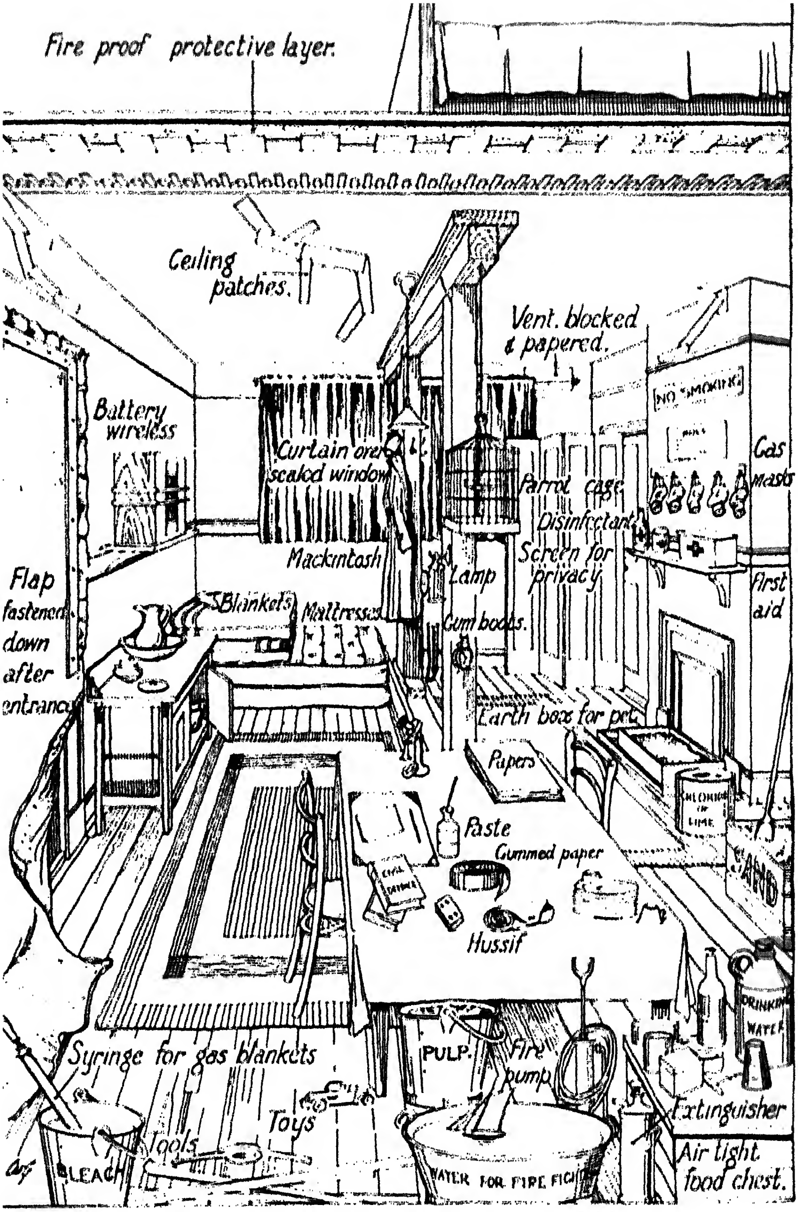


FIG. 25.—The gas-proof refuge ready for occupation.

Table XXXI

Table of Comparative Air Velocities

Velocity of wind: Feet per second	Velocity of wind: M.p.h.	Sensation	Effect
Less than 1½	Less than 1	Calm	Smoke rises vertically
1½–4·4	1–3	Just perceptible	Smoke just drifts, wind vanes not moved
5·9–10	4–7	Light breeze	Wind felt on face, leaves rustle, wind vanes move
11·8–17·5	8–12	Gentle breeze	Leaves and small twigs in constant motion, wind extends light flag
17·5–32	13–22	Moderate breeze	Sways branches of trees, blows up dust and paper before it
34–47	23–32	Fresh breeze	Sways whole trees, blows small branches along ground. Slightly hinders walking
48–105	33–72	Strong gale	Breaks branches, loosens bricks from chimneys, hinders walking decidedly
105–147	73–100	Hurricane	Complete destruction of almost everything in its path

Note. To convert feet per second to miles per hour multiply by 0·684.
88 ft. per minute = 1 m.p.h.

Note. If the wind exceeds 12 miles per hour velocity, gas attacks need not be expected, as the wind dissipates the gas.

Table XXXII

The Leakage through Cracks may be computed from the Figures given in the Following Table.

Wind velocity [illegible] component [illegible] window.	Leakage in cubic feet per hour per foot run of crack. Double hung sash windows. Without weather strips – Wood	Without weather strips – Metal	With weather strips – Wood	With weather strips – Metal	[illegible]	[illegible]	[illegible]
5	49	20	4	6	[illegible]	[illegible]	[illegible]
10	62	45	6	18	52	[illegible]	[illegible]
15	84	70	11	31	80	[illegible]	[illegible]
20	124	96	22	40	116	[illegible]	[illegible]
25	161	125	34	60	152	[illegible]	[illegible]
30	233	153	59	70	[illegible]	[illegible]	[illegible]
40	309	215	87	110	[illegible]	[illegible]	[illegible]

before it has had time to be effective. To move away from an advancing gas cloud one must, of course, keep ahead of the wind.

TABLE XXXIII

A man walking briskly covers .	4 m.p.h.
A horse at a trot . . .	8 ,,
A horse galloping . . .	12 ,,

Cars could only cover what ground the congested roads would permit.

1. Brick Walls

Brick walls for gas-proofing purposes ought to be a minimum of 9 in. thick plastered on the inside. If the pointing is defective, this should be made good and porous brickwork treated with a cement wash and two coats of petrifying liquid All cracked plaster should be made good, as previously described, papered all over and varnished. All holes should be solidly filled and defects afterwards caused by birds or rodents immediately made good.

2. Concrete Walls

Solid concrete gas-proof walls should be at least 5 in. thick, plastered, papered and varnished on the inside and cement washed on the outside. Two-way reinforcement will minimise any cracking causing leaks.

3. Sand-bag Walls

These should preferably be covered with corrugated iron lining overlapped two corrugations at sides in bituminous mastic joints, and with 6 in. end laps similarly jointed.

In exposed sand-bag walls all cracks and crevices should be caulked with paper pulp or similar material, and walls should be sprayed with decontaminating liquid when the shelters are in use.

4. Fireplaces

Any fireplaces existing in a room selected as a gas-proof shelter should be specially dealt with. The chimneys should be stuffed up with sand in bags, all crevices being filled tightly

with paper pulp entirely to prevent draught. Any cracks in the fireplace through which draughts may come should also be sealed up as recommended for floors, but special precautions should be taken to ensure that the protective measures are not easily blown off by air pressure changes, which occur when explosions take place in the near vicinity.

To this end strong plywood should be cut to fit over the opening and fixed thereto by any appropriate means, preferably with screws—the joint being bedded on a seating of putty.

Metal-faced plywood is more gas proof, and should be used in preference to uncovered plywood. A flat steel sheet will also be effective, but the edges should be carefully sealed down with gummed paper pasted on and varnished.

New shelters should be constructed without fireplaces.

5. Ventilators

Any air-bricks or ventilators in walls of a gas-proof shelter should be carefully filled with paper pulp and plaster of paris. The whole surface should then be twice papered over and varnished. It is important that every vent or grating in the building and through which air might circulate should be stopped up, as this will improve the gas resistance of the shelter by minimising air movement about it.

No ventilation openings should be constructed in walls of new shelters.

6. Pipes, Basins, etc.

Any waste pipes or overflow pipes leading to the outside should be plugged, and also any hole of any kind through which air might seep should be sealed up.

7. Windows

Windows are a weakness in any protective construction, and if they exist in a room selected for use as a gas shelter they should preferably be removed, the opening bricked up and the wall gas-proofed.

If this is not possible they should be provided with splinter and blast protection, as described on pp. 211 *et seq.*

If protection on the lines indicated above cannot be given, a substantial degree of protection may be secured as below.

(*a*) The glass can be replaced by a vitreo colloid material, such as cellastoid, $\frac{1}{10}$ in. thick, reinforced with strong wire-netting in close contact with it and fixed rigidly to the frame into which the glass substitute is "glazed."

Alternatively, a non-inflammable cellulose acetate thermoplastic material known as super "Armourbex" may be used.

It is a clear "Bexoid" $\frac{88}{1000}$ in. thick reinforced with $\frac{1}{2}$ in. wire mesh welded at every crossing.

Sheets 61 × 27 in. are supplied by the British Xylonite Co. Ltd. at 31*s*. 6*d*. per sheet.

The "glazing" should be made gas-tight with putty and the window closed tight, wedged up and fixed with all cracks caulked with paper pulp—edges being covered with two layers of strong paper pasted down and varnished.

(*b*) One-sixty-fourth inch sheet celluloid can be stuck to the existing glass with cellulose varnish and backed up with strong galvanised wire-netting or expanded metal of small mesh, as described above. The rest of the window would be gas-proofed, as before described.

(*c*) The re-glazing of the window with $\frac{1}{4}$ in. internally wired glass can be undertaken, but although this treatment would minimise the danger from flying fragments of glass, cracks are liable to develop and gas be thus admitted.

(*d*) Some degree of protection can be secured by pasting ordinary commercial wrapping cellophane on each side of the existing window glass, using cellulose varnish for the purpose.

In every case the precautions recommended for window protection against blast pressures and splinter penetration should be undertaken.

8. Doors

Undoubtedly the best type of door for gas-proof shelters is that shown in Fig. 81 and described on p. 230. Another strong type is shown on Fig. 84 and described on p. 231. Apart from the "air lock" described hereafter all doors to gas-proof shelters should be made airtight.

This can be done by fixing rubber draught strips all round the door stops, so that when the door is closed and latched the strips are compressed. A draught-excluder should also be fixed to the bottom of the door, and care must be taken to see

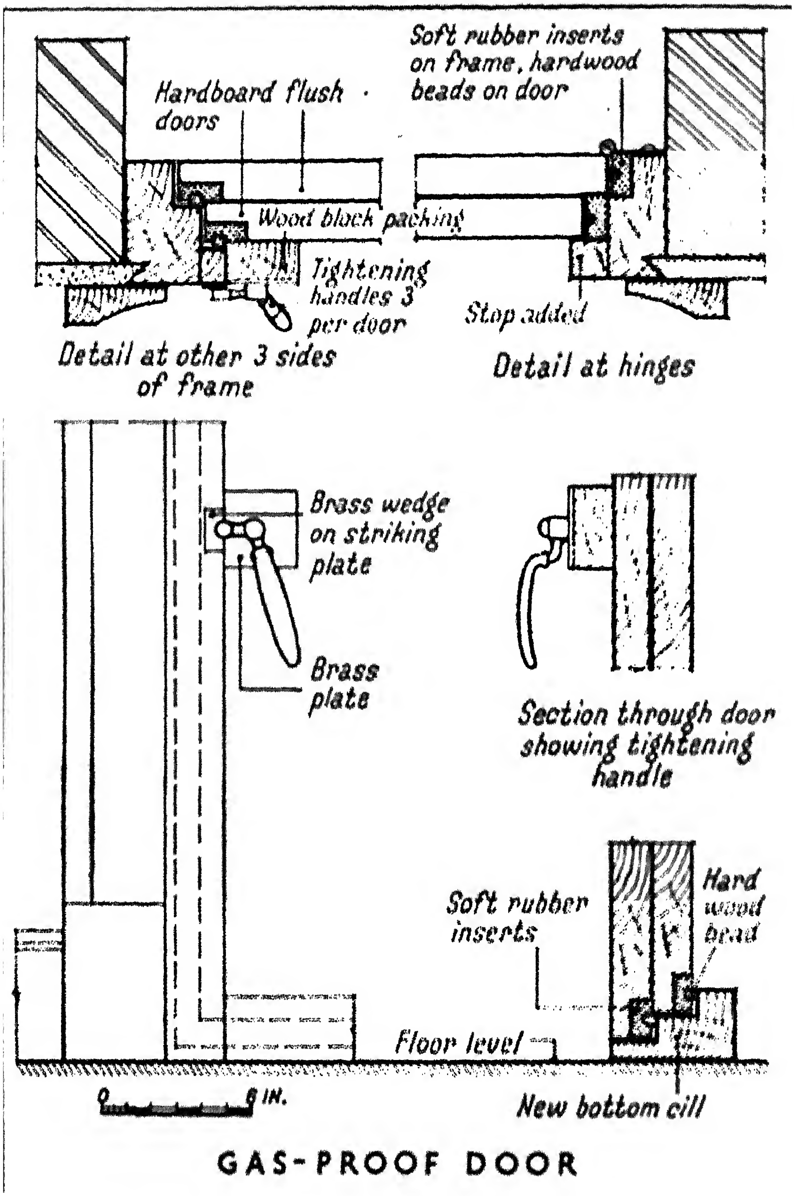


FIG. 26.—Light type of gas-proof door suitable for refuge within a building.

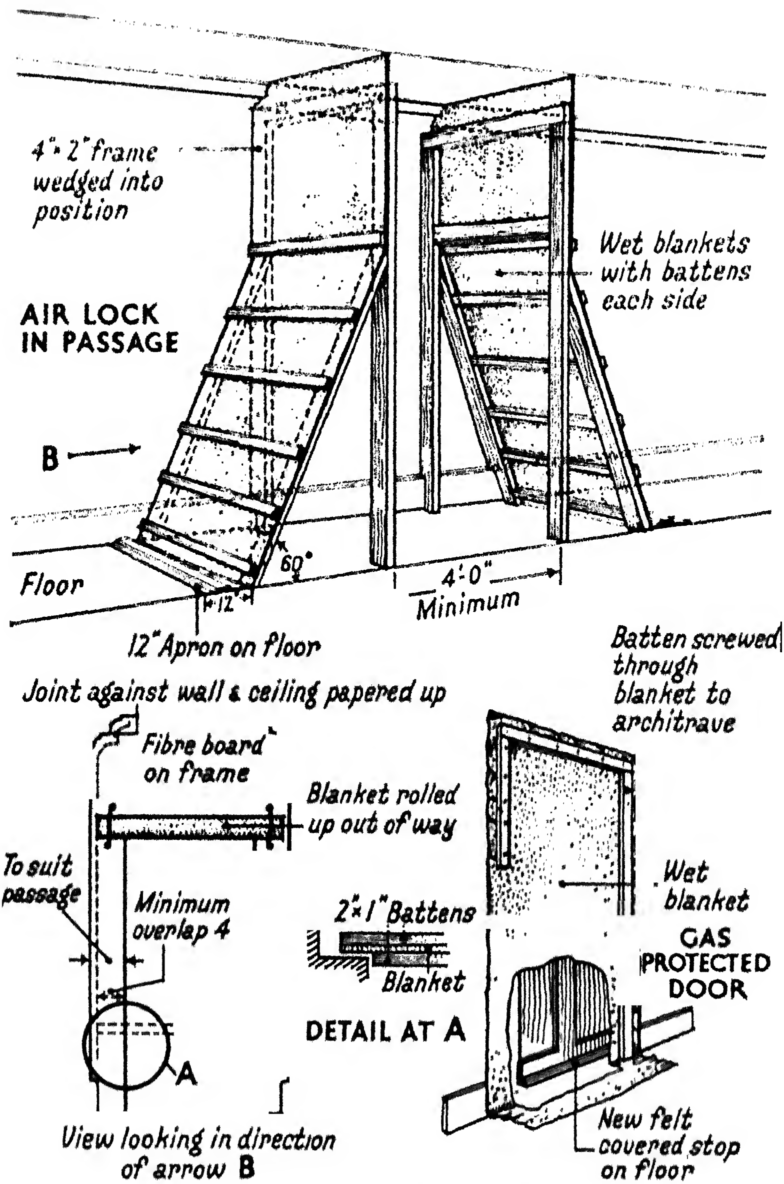


FIG. 27.—Air lock in corridor in building, and method of fixing gas blanket over ordinary door.

that it is really a good fit. In addition to this, a felt-covered door stop should be nailed to the floor.

Keyholes must be blocked up and any cracks in the door caulked with plaster or paper pulp and covered with strips of gummed paper, afterwards varnished.

If the door is an old one and has dropped, leaving a gap top and bottom when closed, larger stops or additional ones must be used.

Cracked or broken wall plaster at edge of door frame must be made good as described for walls, and as the whole construction may have to resist considerable vibration strong brown paper edging folded down the middle before fixing should be gummed on to provide an elastic gas tight joint.

An excellent gas proof door can be made, as shown in Fig. 26, and hung in any standard opening, providing a double gas check round all four edges.

Joseph Sandell & Co. Ltd. supply an A.R.P. door to the following specification:—

Solid core, alder, beech or oak face, edge rebated for gasket; gasket, continuous band of $1 \times \frac{3}{4}$ in. Dunlopillo covered with $\frac{1}{16}$ in. solid rubber; fastenings heavy refrigerator type, or mortice bolts, cill and stops provided. Prices from 65s. each.

A more primitive form of gas protection can be constructed with a blanket fixed over a door. The blanket should be fixed by strips of wood on the outside of the door, the fastening being stopped some 5 ft. above the floor level on the side away from the hinges and the bottom left loose at that corner so that it can be lifted up for people to get through. Twelve inches of blanket should be left trailing on the floor to prevent air getting underneath it. The blanket should be kept wet (see Figs. 27 and 28).

The arrangements may be prepared in readiness and the blanket fixed with thumb-screws through the battens. In an emergency, when the shelter is occupied during a gas warning, the edges of the door should be covered with gummed paper strips.

9. Entrances

All entrances to gas shelters should be screened with splinter-proof protection, as described on p. 38, and be provided with an air lock, as described below and as shown in Figs. 28 and 29.

OUTER GAS-PROOF CURTAIN OF PAIR AT ENTRANCE TO SHELTER

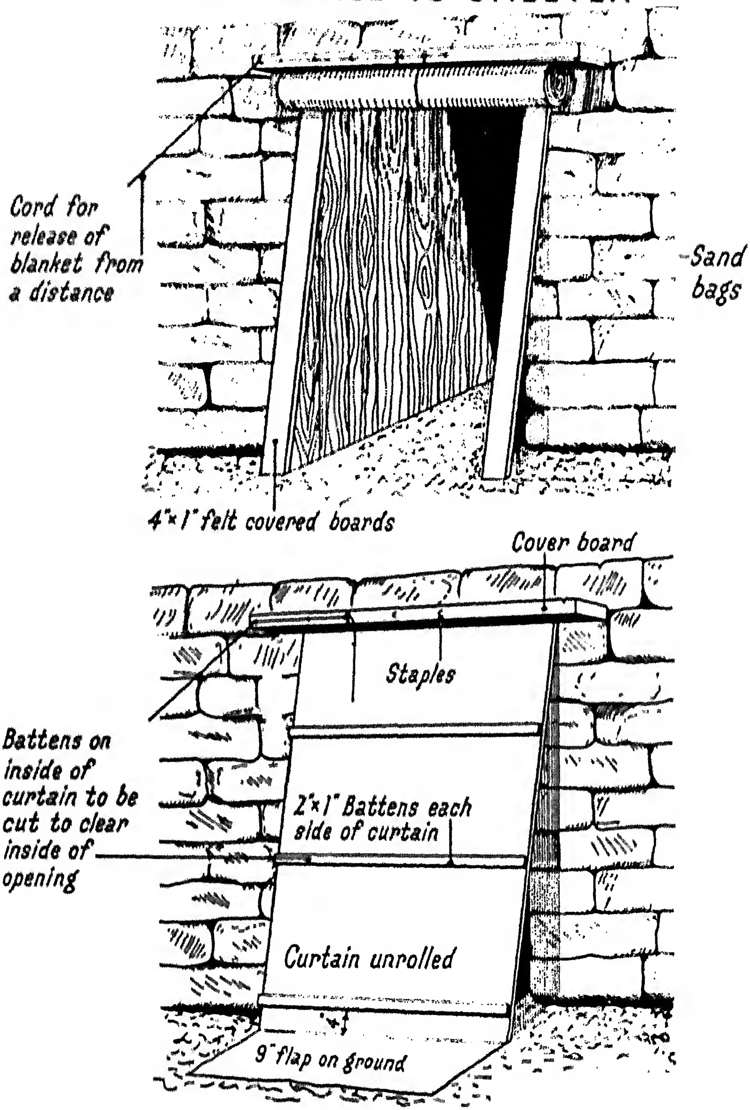


FIG. 28.—Gas-proof curtain for shelter entrance.

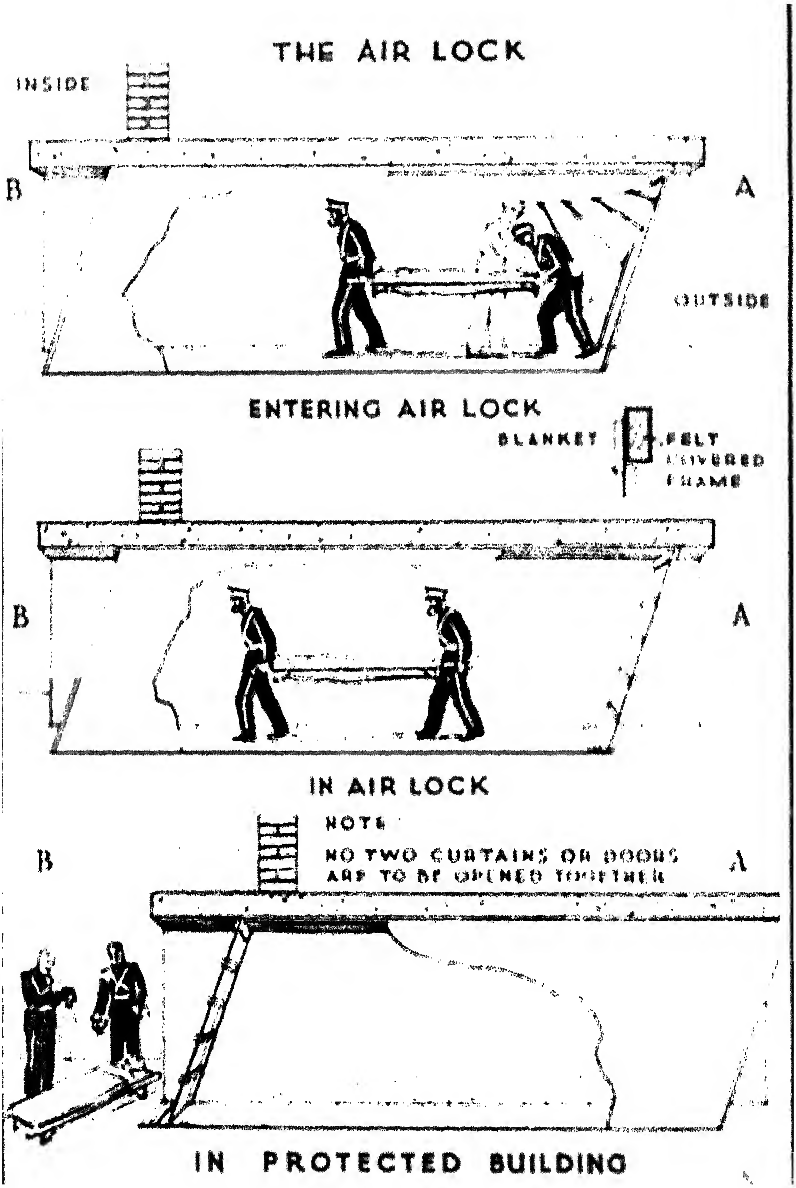


FIG. 26. Arrangement of air lock at entrance to protected building.

10. Air Locks

An air lock doorway is an enclosed passage-way with a door at each end, the passage being deep enough to prevent a man passing through to operate both doors at once. The minimum length of the passage-way should be 4 ft., as shown on Fig. 27, or 10 ft. in the case of medical stations, when the passage must be sufficiently deep to accommodate two men carrying a stretcher (see Fig. 29).

The doors can be of the water-tight and blast-proof type as shown on Fig. 81, the gas-proof internal type doors shown on Fig. 26, or merely gas-proof blankets as shown in Figs. 27 and 28. The blankets should rest on frames inclined at 80 degrees to the horizontal, the overlap at sides being at least 4 in., and at the bottom at least 12 in. The blankets should be fixed at the top with a 2 × 1 in. wood batten, and others of similar section should be fixed at intervals of 24 in. horizontally across the blanket to keep it straight and weight it down.

The battens should be fixed in pairs, the inner ones being short enough to pass easily between the clear opening of the frame and the outer ones being long enough to pass well over and rest on the frames (see Fig. 27).

The blankets should be kept wet with fresh decontaminating solution or ordinary water if the former is not available.

In all air locks a tray of fresh bleaching powder should be kept on the floor, so that persons entering may be able to shuffle both feet in it to decontaminate boots or shoes, which may have persistent gases like mustard gas adhering to them.

A person entering an air lock after being exposed to contamination should remove his outer garments in the air lock and leave them there for decontamination before entering the gas-protected shelter.

On no account should both ends of an air lock be opened at one time ; when the external air is quite free of gas the air lock should be freely ventilated. This may be accelerated by fanning the air to create a draught. If the shelter is below ground a natural draught may be created by making a small fire in the shelter or by using electric heaters.

11. Testing Gas-proof Shelters

From what has already been said, it will be realised that it will be practically impossible to make a shelter of any kind absolutely and completely gas-proof.

The Cambridge Scientists Anti-War Group have evolved a convenient method of measuring the degree of gas-proofness of a shelter or room by ascertaining what they call the "leakage half-time," *i.e.*, the time required for a gas concentration in the room to fall to half its intensity. That is to say, if a gas concentration in the room were 2 per cent., and this were reduced by leakage to a 1 per cent. concentration in, say, three hours, the "leakage half-time" for the room in question would be three hours.

This measure is purely a function of the leakage, and is independent of the particular gas concentration used.

As previously explained, the leakage is much increased by air movement external to the shelter and this varies with the wind.

A gas-tight food store of reinforced concrete lined with galvanised iron with edges overlapped 2 in., pasted up with paper and smeared with vaseline had a leakage half-time of 300 hours, normal above ground shelters having three to ten hours leakage half-time.

The Cambridge scientists conclude from their experiments that the gas leakage is not so much due to diffusion—molecule by molecule—as to "mass flow" of the gases, and that if the concentration of the gas on one side of the wall is higher than on the other side gas will go through the wall at the same rate, either into or out of the room.

All gases behave similarly when mixed with air, and the experiments carried out with carbon dioxide will therefore give a clear indication of the performance of the rooms tested when subjected to poison gas concentrations.

A simple test of the protection afforded by a gas-proof room consists of timing the penetration of the odour of amyl acetate when exposed on the outside of the room. The concentration of gas which can be smelt is about the same as that of an amount of mustard gas which would prove fatal in one hour.

In a room having a leakage half-time of two and a half hours

the smell was detected in five minutes average, but in a room with leakage half-time of nine and a quarter hours the smell was not observed at all.

Gas penetrating into a proofed room becomes unbearable without a mask in about the time it takes for the smell of amyl acetate to penetrate the sealed room from the outside.

On the *assumption* that gas mask protection is not used in the gas-proofed room, the Cambridge scientists have calculated survival times as below :—

A. When the concentration of gas outside remains constant—as with a prolonged bombardment with persistent gases—the leakages into the room are assumed to occur according to an exponential law. For rooms having leakage half-time periods ranging from ten minutes when unprotected to about ten hours when protected, the following survival times are calculated.

TABLE XXXIV

Leakage half-time for room.	Survival time outside.	Survival time inside room.
10 minutes	4 minutes	12 minutes
	46 ,,	1 hour
	1 hour, 16 minutes	1 hour, 30 minutes
1 hour	5 minutes	31 minutes
	17 ,,	1 hour
	55 ,,	2 hours
3 hours	6 minutes	1 hour
	24 ,,	2 hours
	50 ,,	3 ,,
10 hours	8½ minutes	2 hours
	30 ,,	4 ,,
	1 hour, 5 minutes	6 ,,

B. When the concentration of gas outside is falling exponentially at the rate of reduction to half value in ten minutes, the time it is possible to stay in a gas-proof room without gas mask protection works out to the following :—

TABLE XXXV

...ge half time for room	Lethal dose in air outside	Lethal time in r...
10 minutes	2·5 minutes	10 minute
	14 ,,	30 ,,
	36 ,,	1 hour
1 hour	7 minutes	1 hour
	18 ,,	2 hours
	28 ,,	3 ,,
3 hours	6 minutes	2 hours
	$12\frac{1}{2}$,,	4 ,,
	19 ,,	6 ,,
10 hours	$3\frac{1}{2}$ minutes	4 hours
	8 ,,	8 ,,
	12 ,,	12 ,,

If the gas proofing is thoroughly carried out and maintained as recommended above, the survival time for unmasked occupants can be extended.

VENTILATION

General Principles

The proper ventilation of air raid shelters of all kinds is of paramount importance, and in order to understand the problem it will be necessary for us to consider the respiratory requirements of man.

Normal air shows the following composition on volumetric analysis :—

	External atmosphere. Per cent.	Inside a "fresh" building. Per cent.
Nitrogen (N_2) . .	79·03	79·03
Oxygen (O_2) . .	20·94	20·90
Carbon dioxide (CO_2)	0·03	0·07

The nitrogen is not absorbed by the lungs in breathing, but the exhaled air contains on the average 0·4 per cent. of carbon dioxide.

The respiratory process consists of :—

(*a*) The absorption of the oxygen from the inhaled air by

the lungs which transmit it to the blood. The oxygenation of the blood is a continuous process and is vital to the renewal of the cells, tissues and nerve centres of the body.

(*b*) The discharge of CO_2 in the exhaled air charged with moisture and at increased temperature.

The respiratory exchange depends upon the state of activity of the body, and the relation is shown in the following table :—

TABLE XXXVI

RESPIRATORY EXCHANGE OF MAN UNDER VARIOUS DEGREES OF EXERTION

Cubic Feet per Minute

	Cubic Feet of Air Breathed.	Cubic Feet of Oxygen Consumed.	Cubic Feet of CO_2 given off.	Heat Produced, in B.Th.U. per min.
Resting . .	0·275	0·008	0·007	4·6
Standing still .	0·373	0·012	0·009	6·0
Walking—				
2 m.p.h. . .	0·666	0·028	0·024	15·0
3 ,, . .	0·888	0·038	0·033	21·6
4 ,, . .	1·330	0·057	0·050	31·2
4½ ,, . .	1·670	0·072	0·064	39·1
5 ,, . .	2·180	0·090	0·086	50·4

Respiratory exchange is the combustion within the body, and by which carbon and hydrogen of the animal tissues are combined with oxygen to form carbon dioxide and water.

The gas exchange establishes the carbon balance of the organism, determines the nature of the substances catabolised and measures the total metabolism.

Increase of CO_2 in the air breathed is more serious than loss of oxygen, whilst the lack of cooling increases the temperature and pulse rate as well as the consumption of oxygen, due to the increased metabolism.

The nervous state of alarm set up by a realisation of restricted breathing conditions only serves to aggravate the position.

The physical processes described above result in the generation of heat and moisture, which must be dissipated from the body if the correct blood temperature of 98·4° is to be maintained.

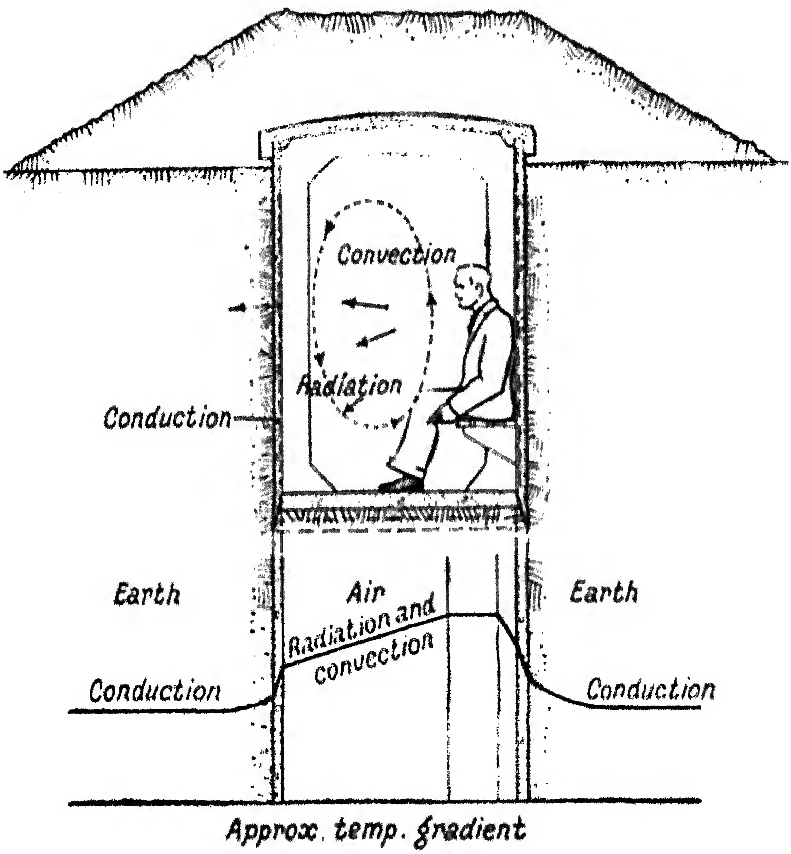


FIG. 30.—Showing heat dissipation from the occupants of buried shelters by radiation, convection and conduction.

A very small rise in blood temperature is sufficient to produce a condition equivalent to that of fever, and researches have shown that a rise of $1\frac{1}{2}°$, if maintained for three hours, is likely to have very serious consequences.

A man in a state of slight activity—as, for example, seated and playing cards in a shelter—would emit about 400 B.Th.U.

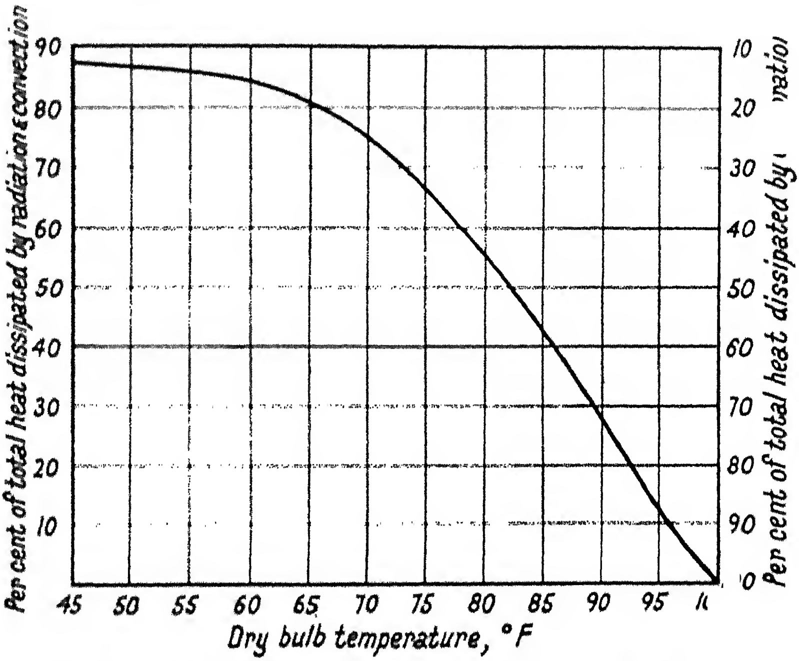


FIG. 31.—Relation between heat loss from the human body by evaporation, radiation, convection and dry bulb temperature. A.S.H.V.E.

of heat, about 0·6 cub. ft. of carbon dioxide, and about $1\frac{1}{2}$ oz. of moisture per hour.

The heat loss is made up partly by sensible heat that is given off directly to the surrounding air by convection and radiation, and partly by evaporation of moisture from the skin and lungs, heat being absorbed in the process of converting moisture into vapour, which is then taken up by the surrounding air (see Fig. 30). While the total is approximately constant for a person in a given state of activity, the proportion of sensible heat to latent or moisture heat varies with the

temperature of the surrounding air, the latent heat of evaporation increasing with a rise in air temperature.

At an air temperature of 98° F. practically the whole of the heat is given off by evaporation of moisture, there being no difference in temperature between the body and the air to induce radiation.

On the other hand, at temperatures below 60° F. very little

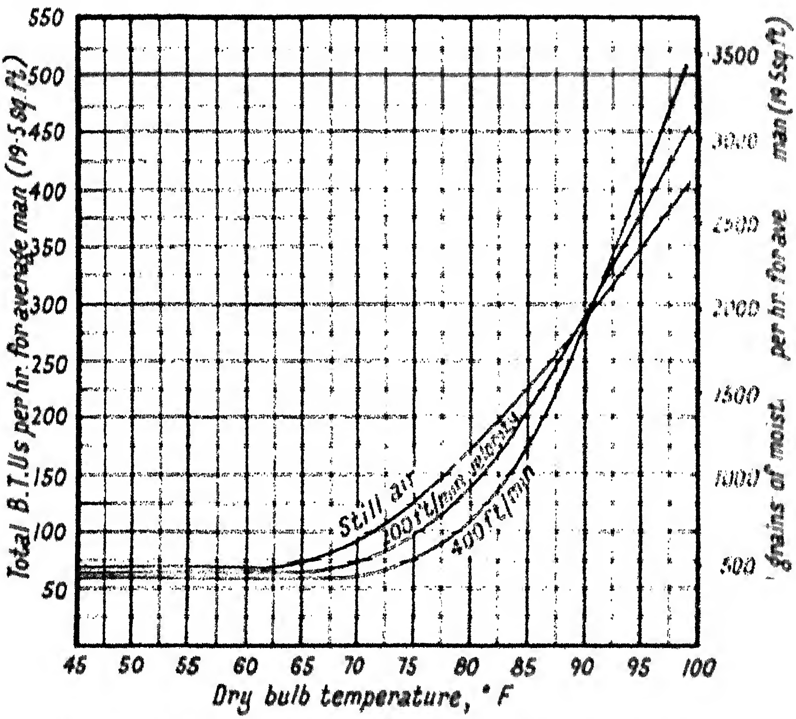


Fig. 31.—Heat and weight loss from human body by evaporation in still or moving air. A.S.H.V.E.

evaporation from the body takes place—the moisture coming almost entirely from the lungs—but the heat dissipated by radiation is at a maximum. Fig. 31 shows the relation between the dissipation of latent heat by evaporation and the temperature of the surrounding air.

At 70° F., for instance, 77 per cent. of the total takes the form of sensible heat and 23 per cent. is used to evaporate moisture (about 1½ oz. per hour).

About 60 per cent. of the former is dissipated by radiation and the balance by convection, while about half the latent heat component is dissipated *via* the respiratory system and one-half *via* the skin.

The above proportions obtain in still air in a closed shelter, and are naturally subject to wide variation with changes in rates of ventilation and air movement (see Fig. 32).

The importance of avoiding too close packing of the people in a shelter will, however, be apparent as people in the middle of a shelter would be surrounded by radiating bodies and would not have free access to the bounding surfaces of the shelter, which ultimately transmit and dissipate all the heat not dealt with by ventilation.

Absorption of latent heat can only take place so long as the surrounding air is unsaturated, and air in an enclosed space will rapidly become saturated unless moisture is extracted from it.

Below are summarised air conditions and their effects on the average person.

TABLE XXXVII

Condition of Air.				Effect.
Temp. Deg. Fah.	Relative Humidity. Per cent.	Oxygen. Per cent.	CO_2. Per cent.	
70–75	50–70	21	0·05	Comfortable conditions in normal shelter.
85	90	—	—	Acute discomfort, faintness and a feeling of suffocation and alarm.
92	90	—	—	A dangerous rise of body temperature, pulse and rate of breathing, accompanying panic.
98 or higher	95–100	—	—	Rapid rise in body temperature inevitable. Conditions extremely dangerous.
		Reduced to 14.	—	Not harmful.
		10	—	Minimum necessary for normal breathing.
			Up to 1·5	Quite innocuous.
			3	Increased blood pressure and headache.
			4	Gradual impairment of respiration due to poisoning effect.
			5 and over.	Dangerous.

GENERAL REQUIREMENTS OF VENTILATION

Proper ventilation depends upon the following factors

(*a*) Volume of air .
(*b*) Temperature of air
(*c*) Relative humidity
(*d*) Air motion . .

These factors in combination contribute to what is termed "effective temperature."

(*e*) Purity of the air in reference to its freedom from odours, dust, toxic gas or smokes, bacteria and other objectionable matter.

(*f*) Air movement and distribution.

(*g*) Psychological effects.

A comparatively small air supply will suffice for the respiratory requirements alone, but a large volume may be necessary for the maintenance of health and comfort.

Ventilation—Type of Shelter

For a given number of persons, apart from the consideration of mere floor space, the size of a shelter is determined by heat and breathing space. In respect of ventilation three types of shelter may be recognised.

1. *Open Shelters.* Ventilated either naturally by way of the normal exits and entrances, or by ducts with or without forced draught, but without gas filtering units. The respirator is the personal protection against gas.

2. *Sealed Shelters.* Built to be gas-tight and fitted with air lock. The shelter is intended to give collective protection against gas and respirator need not be worn in the shelter.

3. *Ventilated Gas-protected Shelters.* Built to be gas-tight, fitted with air lock, with mechanical plant drawing air through gas filters, and with non-return escape valves.

Generally speaking, the open shelter is indicated as the normal type, the sealed shelter is suitable under domestic control, and the ventilated gas-protected shelter would be appropriate for special shelters such as control centres.

Various recommendations for maximum occupancy have been issued by the Air Ministry and Home Office, and standards have been established based on wall area and on air volume in accordance with the type of shelter.

The limiting factors determining maximum occupancy in all cases are :—

1. That the shelter has a sufficient amount of surface area per occupant to ensure dissipation of his bodily heat without causing too great an increase in the temperature of the air in the shelter.

2. That the shelter has a sufficient rate of ventilation or a large enough air volume per person to prevent the carbon dioxide concentration exceeding 2 per cent. during the anticipated period of occupation.

Physiological Basis

The number of persons that can be accommodated depends on (1) the temperature to which the air in the shelter is raised during the occupation; (2) the humidity of the air in the shelter; (3) the extent to which the air becomes charged with carbon dioxide; (4) the velocity of air movement inside the shelter; (5) the temperature of the inner surfaces of the shelter (*i.e.*, the walls, floor and ceiling).

Stuffiness is primarily the result of high humidity, together with the accumulation of odours inseparable from a perspiring crowd.

In Air Raid Precautions Handbook No. 5, Structural Defence,[5] issued by the Home Office, the following recommendations appear:—

Excluding special cases, such as shelters which, owing to the exigencies of the site conditions, have to be accommodated next to boilers, hot pipes, etc., and based upon numerous experiments carried out in this country, the following tables of occupancy have been drawn up:—

TABLE XXXVIII

Period of Occupation.	Unventilated Gas-tight Shelters Total Surface Area Required per Person.	Mechanically Ventilated Shelters. Total Surface Area Required per Person if Shelter is Ventilated at the Rate given opposite in Column 4.	Ventilation Rate per Person.
		3	4
3 hours	75 sq. ft.	30 sq. ft. if shelter is above ground.	450 cu. ft. per hour.
		40 sq. ft. if shelter is above ground, or 20 sq. ft. if shelter is under ground.	150 cu. ft. per hour.
12	100 ,,	50 sq. ft. if shelter is above ground, or 25 sq. ft. if shelter is under ground.	450 cu. ft. per hour.

The application of the above table to a shelter measuring 16 ft. long, 12 ft. wide and 11 ft. high is illustrated by table below. The total surface area is 1,000 sq. ft.

Table XXXIX

Conditions of Shelter	Period of Occupation Hours	Total Surface Area Required per Person Sq. ft.	Number of Persons Accommodated
Unventilated, gas tight, above or below ground	12	100	10
" " "	4	75	13
Mechanically ventilated, 450 cu. ft. per hour, per person, above ground	12	50	20
Mechanically ventilated, 150 cu. ft. per hour, per person, above ground	4	40	25
Mechanically ventilated, 450 cu. ft. per hour, per person, above ground	4	30	33
Mechanically ventilated, 450 cu. ft. per hour, per person, below ground	12	25	40
Mechanically ventilated, 150 cu. ft. per hour, per person, below ground	4	20	50

The tables on this page have been prepared to show the number of people who can safely be accommodated in rooms of typical dimensions and under various conditions. They all relate to shelters where occupants are at rest. In situations where personnel will be expected to remain at work with normal efficiency, higher rates of ventilation and greater surface allowances will be necessary.

Table XL.

Capacity of Unventilated Gas-tight Rectangular Shelters whether Above or Below Ground Level

Dimensions of Room in Feet.			Number of Occupants for Periods not exceeding	
ngth.	Width.	Height.	4 Hours. (Total Surface ÷ 75.)	12 Hours. (Total Surface ÷ 100.)
12	11	10	10	
16	14	10	14	
21	16	11	20	
24	16	15	26	20
26	18	15	30	23
35	20	15	41	30
45	20	15	50	37

Table XLI

Capacity of Mechanically Ventilated Shelters Above Ground

Dimensions of Room in Feet.			Number of Occupants when Ventilation Rate is :		
Length.	Width.	Height.	150 cu. ft. per Person per hour for Periods up to 3 hours. (Total Surface Area ÷ 40.)	450 cu. ft. per Person per Hour for Periods up to 3 hours. (Total Surface ÷ 30.)	450 cu. ft. per Person per Hour for Periods up to 12 Hours. (Total Surface ÷ 50.)
9	7	8	10	13	8
9	8	10	12	16	10
12	8	10	15	20	12
13	12	10	20	27	16
16	12	11	25	33	20
17	15	11	30	40	24
22	18	10	40	53	32
24	15	10	37	50	30
26	15	15	50	67	40

Table XLII

Capacity of Mechanically Ventilated Underground Shelters

Dimensions of Interior in Feet.			Number of Occupants when Ventilation Rate is :	
Length.	Width.	Height.	150 cu. ft. per Person per Hour for Periods up to 3 Hours. (Surface ÷ 20.)	450 cu. ft. per Person per Hour for Periods up to 12 Hours. (Surface ÷ 25.)
9	9	9	24	20
12	8	10	30	24
14	11	10	40	32
16	12	11	50	40

In the Revised Code [173] under the Civil Defence Act the space specified for shelters ventilated naturally by way of the normal entrances and exits, but without mechanical ventilation, is as below :—

For trench or tunnel shelters wholly or partly below ground level, where there are openings to the air at either end of each bay or traverse, and where not more than fifty persons are accommodated in any one bay or traverse, or where the complete shelter does not accommodate more than twelve persons, there shall be not less than 3¾ sq. ft. of floor area for every person in the shelter.

For other shelters, wholly or partly below ground level there shall be

Not less than 6 sq. ft. of floor area per person ;
Not less than 50 cub. ft. capacity per person ;
and Not less than 25 sq. ft. of surface area per person, whichever gives the least accommodation. (See also p. 128).

Some idea of the relative density of occupation of shelters can be gained by consideration of the following table :—

TABLE XLIII

Situation.	Square Feet of Floor Space per Person.	Air Normally Required for Ventilation.	
		Cubic Feet per Minute per Square Foot of Floor.	Cubic Feet per Hour per Person.
Average office .	25	0·5	750
Popular restaurants	10	3	1,800
Theatre seating .	4	4	960
Public vehicle seating	3·2	5	960
Crowd standing .	1·5	17	1,530
Dense crowding .	1	33	2,000

From the above it will be seen that even when the highest recommended occupancy is adopted, a shelter will be far from full, and shortage of accommodation and lack of organisation and drilling of the public is almost bound to result in some degree of overcrowding of shelters in the early stages of hostilities.

A shelter designed for fifty people and having a floor area of 300 sq. ft. might in a panic be packed to capacity with 300 people with disastrous results.

Mechanical Ventilation

The general advantages to be derived from mechanical ventilation of A.R.P. shelters may be summarised as below :—

(*a*) The safe occupancy of a shelter, both in numbers of persons and periods of occupation, can be increased by mechanical ventilation, thus necessitating a smaller shelter for a given number of persons.

This reduces the size of the target and lowers structural costs to a degree that often covers the cost of the ventilation plant.

(*b*) Ventilation maintains the air in its desirable condition, and enables filters to be used to eliminate dust and poisons.

(*c*) The mechanically ventilated shelter is always ready for use and does not need periodic evacuation for cooling and drying, as is the case with the closed unventilated shelter.

(*d*) The pressure, or positive pressure, it is possible to maintain in a shelter ensures that all leaks will be outwards, thus minimising danger from imperfect gas-proofing.

(*e*) The vitiated air leaving the shelter can be directed through lavatories, air locks, decontamination compartments to ventilate them continuously outwards.

(*f*) The effects of overcrowding are much less serious.

(*g*) The chances of persons catching colds on leaving the shelter are minimised.

Open-Circuit Mechanical Ventilation

1. *Without Gas Filters.* This system has the advantages of low first cost, compactness and high capacity, but has certain very definite disadvantages.

Dust, poison gas or smoke may be drawn into the shelter in relatively high concentrations and the shelter might be contaminated with mustard gas.

The gas mask is an essential protection, but is no guarantee that panic will be prevented.

2. *With Dust, Gas and Smoke Filters.* Such systems give complete protection against dust, gas and arsenical smokes, ensure longer comfort conditions—as gas masks need not be worn—and thus reduce chances of panic.

The complete apparatus normally includes fan, trunking, valves and one or more filtration units.

The containers for filtration units are the individual containers which hold the active gas-filtering material, and must successfully pass the Home Office tests set out in the table overleaf.

TABLE XLIV

HOME OFFICE TESTS FOR GAS FILTERS

	Concentration.	Service Time.
Chloropicrin . .	One part per 500 parts of air by volume	90 minutes
Phosgene . .	One part per 100 parts of air by volume.	30 minutes
10-chloro-5 : 10-dihydrophenarsazine	45 milligrams per cubic metre of air (≈ 1 part in 485,000 parts of air).	15 minutes

All tests to be made at the rated output of the filter.

General Requirements of Ventilating Plants

(*a*) WITHOUT GAS FILTERS

Inlet. The inlet should be taken from some point where it is considered to be as free as possible from gas. Home Office handbooks suggest a minimum height of 30 ft., but local conditions must be taken into account. Tests have shown that in amongst buildings there are many vertical currents, as well as thermal currents, and therefore one cannot be sure that gas, if present, would lie below 30 ft. from the ground. Possible damage to the inlet shaft by splinters and blast must be considered, and therefore the inlet shaft should be placed where it can be protected by the adjoining building, if this exists.

Asbestos cement and C.I. pipes are preferable to W.I. and steel.

Shut-off Valve. It is necessary that a completely gas-tight shut-off valve be fitted, controllable from the shelter.

Dust Filter. It is recommended that a dust filter be fitted to remove masonry and other heavy dusts. A number of casualties in Spain were attributable to asphyxiation by dust brought into the shelter by the ventilation plant.

Heater. In some cases it is advisable to incorporate a heater to dry out the shelter before occupation. Unused underground chambers become damp, the air approaching 100 per cent. relative humidity.

Fan. The fan should be designed to give its rated output

against the total resistance of the circuit, including all ducting, and an allowance of ¼ in. w.g. for plenum.

Motor and Starter. Consideration should be given to the fact that the equipment may have to remain idle for long periods in a very damp atmosphere. The electrical equipment, in particular, must be chosen with this point in mind. There should be an ample margin of power, so that the unit will run reliably for long periods or when the filter is by-passed or when the air duct is inadvertently closed.

Alternative Drive. Some means must be provided for operating the fan in the case of power failure. This may be manual in the case of small shelters, and for large shelters a stand-by Diesel generator may be used. Alternatively, in large shelters a number of small fan sets—each small enough for manual operation—can be utilised. The sets may be installed wholly within the shelter space.

Distribution of Air. It is essential that the air be distributed efficiently, so that draughts are avoided and no "dead pockets" formed. One of the chief causes of discomfort is the layer of saturated air covering the body, and sufficient air movement must be obtained to remove this. This can be done by disturber fans, but can be achieved more efficiently by correct distribution ducting fitted with nozzles, so that the direction and velocity of the air flow can be set to suit local conditions. In small shelters, or shelters of the long and narrow type, it is often possible to dispense with distribution ducting, if the positions of the plant and the air outlet can be chosen so that the air will flow through the shelter without leaving pockets of dead air. Distribution ducting should normally be at high level. The Office of Works adopt a flow of 26 c.f.m. per nozzle about 2 in. diameter. Velocity about 1,000 ft. per minute.

Evacuation Valves. In shelters which are reasonably airtight, the air is evacuated through one or more evacuation valves. These are of the non-return type, so that while air can flow outwards the valves would automatically close and prevent ingress of air should there be a burst and consequent pressure outside the shelter. The valves are opened by the internal pressure, or plenum, in the shelter, and are set to open when the predetermined plenum has been obtained.

(*b*) Ventilating Plant with Gas Filters

Inlet. The same remarks apply here as for the inlets for non-filtration ventilating plants, excepting, of course, that it is not so necessary to have the inlet arranged to avoid drawing in gas. It is, however, an advantage to draw as low concentrations as possible, in order to extend the life of the filters. It is important to arrange the inlet in a protected position, so that the danger of it becoming damaged or blocked is as small as possible. A convenient method of arranging the inlet of an underground shelter is to bring it up about 2 ft. above ground level to avoid flooding and to protect it by means of a small concrete box about 2 ft. square with louvres on opposite sides, so that if one set of louvres becomes blocked with earth from a burst, those on the opposite side may remain clear.

It is recommended that, where possible, two inlets should be used, so arranged that a part of the building is between them ; thus if a bomb damages one, the other will be protected. If the shelter is in the basement of a building, it is convenient to have one external inlet and one internal, utilising, for example, a lift shaft. This, of course, depends on local conditions. It is essential that the inside of the inlet shafts be treated with an anti-gas composition to prevent corrosion.

Fan. The fan must be arranged to give its full rated output against the total resistance of the ducting circuit, plenum and filters when dirty. This means that when the filters are clean (and the resistance lower) the fan must not give more than its rated output, or the air would not be in contact with the charcoal long enough for complete adsorption to take place. In other words, provision must be made to prevent the filters passing more than their rated quantity of air when they are clean.

Motor and Starter. See remarks above under Non-filtering Plants.

Control Valve. An efficient control valve should be fitted, both for controlling the rate of air flow and for shutting off the plant when not in use.

Flowmeter. A reliable flowmeter is essential for two reasons :—

(*a*) To ensure that the correct air quantity is being handled when operating by power.

(*b*) To indicate the correct speed of operation when working the plant manually.

Manual Operation. Some form of manual operation is essential for use should the current fail. It is found that plants up to about 16,000 c.f.h. can be operated by two persons. Above that output either the plant should be split into two or more units or a stand-by generating plant installed.

The Home Office requirements for manual operation are as follows :—

Capable of being operated by average adults of either sex, or by older children, in shifts of not less than fifteen minutes, and the number of persons required per shift not to exceed 5 per cent. of the number for which the plant is designed. If manual operation is fitted as an alternative to power operation, a reduction in output of 50 per cent. is permissible when the plant is operated manually. No reduction in output is permitted if the plant is not fitted with power operation.

By-pass. All plants should be fitted with a by-pass round the filters, so that dust is not deposited on the filters when the plant is used on occasions when there is no gas present. It should be noted that the by-pass valve must be absolutely gas-proof and easy to operate.

Filters. The acceptable performance of gas filters is laid down in the Home Office specification, and no filter having a lower performance should be considered. The Home Office tests are shown in Table XLIV, p. 132.

A poison gas filter consists essentially of three stages of filtration as follows :—

(*a*) A pre-filter for the removal of heavy dusts, etc.

(*b*) A particular filter for the removal of arsenical and other fire smokes.

(*c*) Activated charcoal for the adsorption of volatile gases.

It is very important that the whole of the filter should be chemically inert, so that no chemical change can occur in storage. All metal parts, casings, etc., should be treated inside with anti-gas composition and any rubber parts should be made of rubber to Home Office specification.

Provision should be made so that the filter elements can be

removed, and replaced on site without difficulty, and it is, of course, essential that replacement supplies be available in wartime.

Mechanical Details. All mechanical details should be so designed, and the materials chosen, so that the plant can be left for long periods in storage in damp atmospheres and will operate efficiently when called upon to do so.

Distribution Ducting. See remarks under Non-filtration Plants.

Evacuation Valves. See remarks under Non-filtration Plants.

Air Quantities. The Home Office have specified the following :—

(*a*) For shelters where persons will be sitting still :—

150 cub. ft. per person per hour minimum.

(*b*) For working spaces :—

450 cub. ft. per person per hour.

For working spaces where the number of persons is unknown or variable, *e.g.*, first-aid posts and decontamination stations, it is recommended that the air quantity be chosen to give a minimum of two air changes per hour in the enclosed space.

TABLE XLV

TESTS ON SHELTERS CONTAINING CARRIER VENTILATION PLANT

			Plenum.	
Type of Shelter.	Number of Persons.	Airlock Doors.	[illegible]	[illegible]
New basement . . .	1,400	Blanket	No valves	0·2"
Old basement . . .	50	Timber	0·14"	0·26"
Bank basement . . .	1,250	Blanket	No valves	0·14"
Basement corridors . .	50	Blanket	No valves	0·2"
Special concrete . . .	200	Steel	0·25"	3·0"
Corrugated steel . . .	50	Steel	0·6"	1·5"
Strengthened basement .	200	Timber	0·25"	0·7"
Large basement . . .	700	Blanket	No valves	0·04"
Strengthened basement .	50	Timber	0·24"	0·41"
Excavated in rock . .	50	Steel	0·25"	1·5"
Concrete (new structure) .	50	Steel	0·25"	0·38"
Town Hall basement (strutted)	150	Timber	0·26"	0·3"

Courtesy N. Forster, Esq., F.A.R.P.I., Carrier Eng. Co.

If cost permits, this should be increased to four air changes per hour.

Plenum. The pressure obtained inside a shelter is a function of the air-tightness of the building and varies according to the total surface, the materials of construction, the age and state of repair, etc.

A plenum of $\frac{1}{10}$ in. w.g. is recommended by the Home Office, but this can be safely increased to $\frac{1}{4}$ in. w.g. when conditions permit. It is considered unnecessary to exceed this figure, and it may be mentioned that even if the plenum is so low that it cannot be measured, it is still there, due to the fact that air is being pumped into the building continuously, and therefore all the leaks will be going outwards. Attempts should be made, however, to seal up the building, so that at least 0·05 in. w.g. is obtained. Plenums obtained in shelters of widely differing types are shown in Table XLV.

Petrol-driven Units

These require a comparatively large amount of air for combustion and for cooling. It is not necessary that this air should be filtered.

It is, however, desirable to house the engine itself in a protected compartment adjoining, but cut off from the shelter proper. The air for cooling and combustion must therefore be drawn in from the outside independently and discharged separately to the atmosphere.

Provision for satisfactory and easy starting should be made, and it is desirable to have a dynamotor of a 12-volt lighting set, with battery of about 60 ampere-hour capacity coupled up. This would be convenient for shelter lighting and for starting, though hand starting is a necessary provision.

A stand-by manually operated drive should always be installed in such a manner that the persons driving it are in the gas-protected shelter.

Noise

The Home Office specify that to avoid distress to the occupants of a shelter, the noise emitted by the ventilating unit and by the delivery of air through the trunking should be as inoffensive as possible and should not exceed 65 phons.

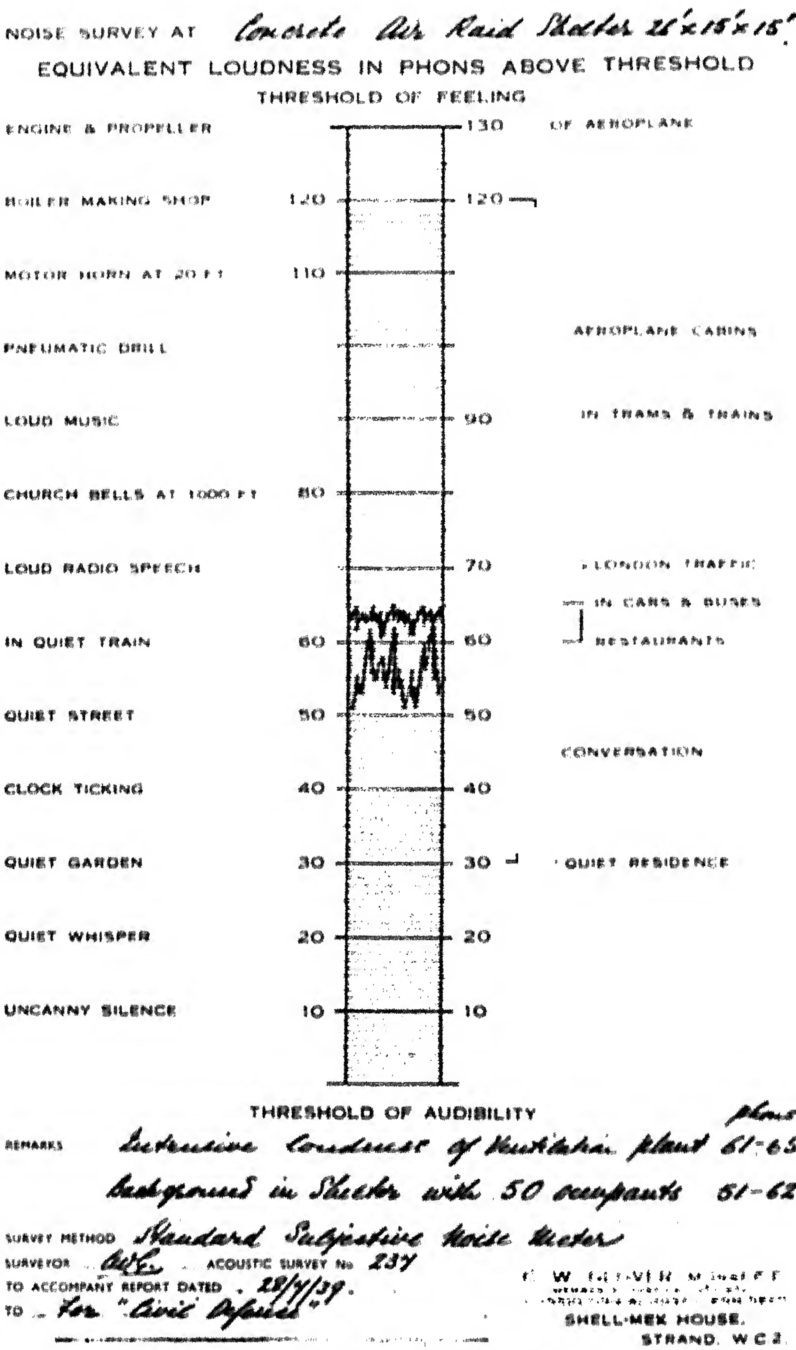


Fig. 33.—Noise test in A.R.P. shelter.

It must be remembered that most air raid shelters have very reverberant interiors—a shelter 26 × 15 × 15 ft. accommodating fifty persons would have a reverberation period of 1·2 seconds when occupied—and noises and the background of conversation would be amplified to an abnormally high equivalent loudness.

The test sheet reproduced in Fig. 33 shows the loudness of sounds in a typical shelter compared with familiar sounds, and clearly indicates that, except to an attentive listener, the noise of the ventilation plant would not be offensive.

Temperature Control

In an exhaustive study of the factors governing the disposal of heat and moisture in shelters, R. R. Poole, B.Sc. F.A.R.P.I., has shown the advantages and economic possibilities of refrigeration.

Application of Refrigeration

" In the shelters so far considered the heat has been absorbed by the walls and the moisture precipitated thereon as dew. A far greater absorption of heat is possible by the use of refrigerated surfaces, the temperature of which is held some 40° to 50° below the air temperature, since the temperature difference is six to eight times as great as that between the air and the walls. The heat transfer coefficient from air to cooled surfaces is, moreover, considerably greater than that of a concrete wall.

" Conventional air-conditioning cooling units of the forced air type could be used for this purpose, but they possess certain disadvantages, the principal one being the necessity for electrically driven fans, which are not easily adapted to emergency drive in the event of failure of the electric supply. In such an event, moreover, provision would have to be made for the drive to the compressor to be transferred to a Diesel or petrol engine.

" To meet these disadvantages a cooling unit has been designed which has the form of a flat ice tank of galvanised steel containing the refrigerating coil. The tank, which measures only 3 in. in thickness, is set up on edge, preferably in the centre of the shelter, so as to expose both its sides for

the direct absorption of heat, and the area of the sides is proportioned so that with the contained ice at 52° F. the heat absorption and moisture condensation supplementing that of the walls will maintain the shelter conditions at a suitable figure irrespective of air supply.

"Generally speaking, the tank area can be made a certain fraction of the shelter inside area and the permissible shelter loading may be determined for a given tank-to-wall ratio.

"The ice tank device possesses several important advantages over any other method of cooling. In the first place, a relatively small refrigerating unit is able to cool and freeze a charge of water over a period of, say, twenty-four hours, and once frozen a short periodical run regulated by automatic low pressure control will suffice to keep the ice frozen. The amount of ice contained in the tank is sufficient to absorb the appropriate proportion of heat from the regulation number of occupants for a total period of twelve hours, thus a quick succession of raid alarms, which, it is anticipated, would rarely exceed three hours each will draw on the reserve capacity of the ice, while the refrigerating unit will run continuously to refreeze the ice thawed during occupation, rebuilding the reserve during 'all clear' periods.

"The long holdover period renders the plant independent of temporary cessation of electric supply; while repair of a broken supply line within the total holdover period would generally be possible, bearing in mind that the reserve is only used at very low rate, while the shelter is unoccupied.

"Enough ice for three-hour occupation would remain after several days shut-down of the machine.

"The humidity in the occupied shelter is maintained somewhat lower than that in the unrefrigerated shelter, a figure of 85 per cent. representing the probable average; a correspondingly higher dry bulb temperature may therefore be tolerated."

By the use of refrigeration, ventilated air would no longer be required to do any cooling, and the air supply could be safely cut down to comply with the oxygen and carbon dioxide requirements, say, to 1 cub. ft. per person per minute.

Poole shows that with a design limit of 80° it is possible to accommodate in a fifty-person tunnel type shelter fitted only

with refrigerated cooling surface equal to 18 per cent. of its total area twice as many persons as would be possible with even a 5 cub. ft. per minute per person ventilation, three times as many as with 2·5 cub. ft. per minute per person ventilation, and three and a half times as many as an unventilated shelter.

The use of refrigeration, therefore, enables the size of the shelters to be cut down, thus reducing the target and making overcrowding less severe.

From an economy standpoint, advantage can be shown by the use of refrigeration, particularly when considering costly shelters giving a high degree of protection and when space is very limited.

In short trench shelters, for instance, a saving of approximately 7s. per person can be shown, and this will approach £5 per head in the case of bomb-proof shelters designed for ventilation with refrigeration.

The Closed or Regenerative System of Ventilation

This aims at maintaining the comfort and safety of the occupants of a shelter by maintaining the hygienic quality of the air in the enclosed space.

It will seldom be adopted on account of the fact that the necessary supply of chemicals, compressed air or oxygen will be expensive to maintain and will need skilled manipulation.

The shelter needs to be hermetically sealed if the loss of valuable air or oxygen is to be prevented and, further, the chemicals are expended whether gas is present or not.

Ventilation Plant

A ventilating plant using the Carrier-Gas-Defence Filter gives a continuous supply of fresh purified air. Tests have been made with all concentrations of poison gases, colloidal smokes and particles, and no trace of these is to be found at the fan outlet. Ventilating plants have been produced in all sizes according to the number of people to be accommodated and to the type of shelter being used.

One great advantage of the system is the low resistance, due to the very large filtering surface. Only a small fan is needed and, should the electric power supply fail, the plant can be

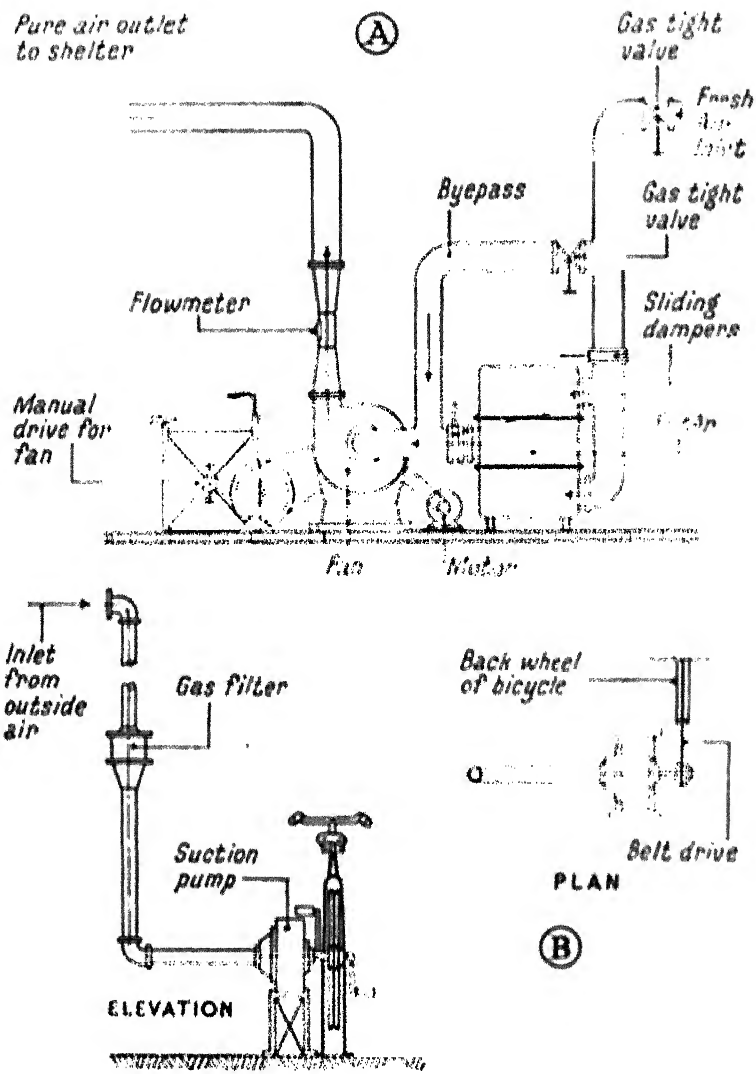


FIG. 34.—Diagrammatic layout of typical gas filtration and shelter ventilation plant. Alternative A shows by-pass for use when changing filter or for ventilating shelter when no gas or smoke is in the vicinity.

operated manually without calling for severe physical effort.

It is often convenient on large installations to instal a small auxiliary Diesel lighting set, which will provide emergency lighting and also power for the fans in case of failure or shutting down of the normal power supply.

Installation

A diagrammatic layout of a typical gas filtration plant is shown in Fig. 34, which is sufficiently self-explanatory. A

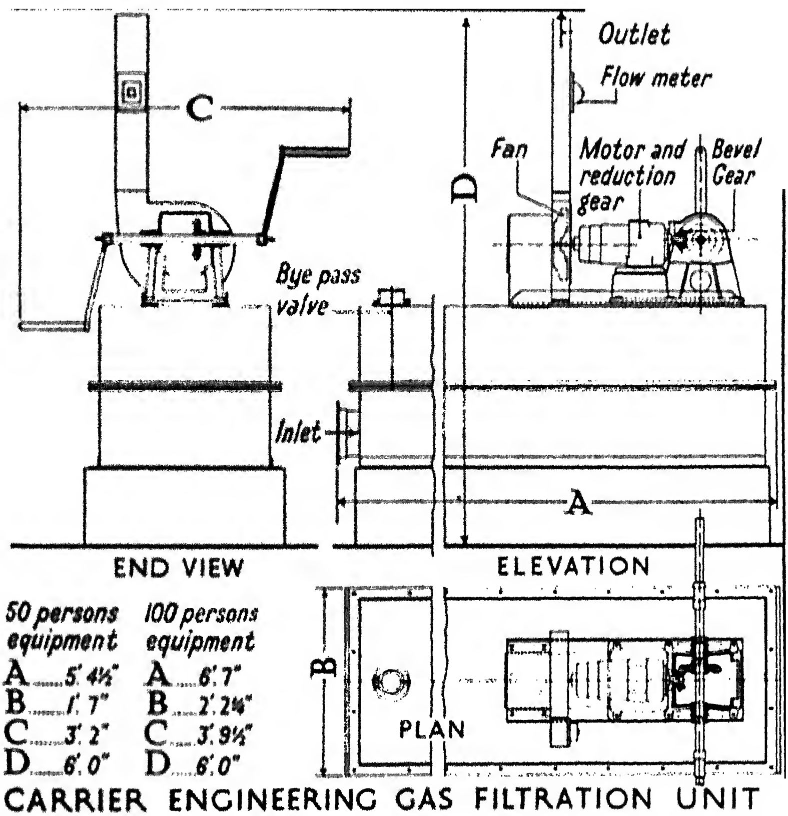


FIG. 35.—Overall dimensions of gas filtration and ventilation units for electric or manual operation.

number of carrier units are also shown in Figs. 35, 36 and 37.

The overall dimensions of the Carrier gas filtration units are given in Fig. 35.

Firstly, there is the fifty-person unit, 7,950 c.f.h. The overall dimensions of this unit, which is complete in every respect, including electric motor and manual drive for the fan, are 5 ft. 4½ in. long by 1 ft. 7 in. wide, and the height of the discharge chimney is 6 ft. from the ground level. To the 1 ft. 7 in. should be added sufficient room for one man to stand either side for turning the handles when the unit is being driven manually.

At the present time supplies of this unit are available, complete in every respect, erected and gas tested on site, for the sum of £82 10s. nett. The prices do not include for distribution ducting or for electrical wiring or builder's work, which, of course, vary on every installation.

The same firm are also in production on a similar unit, but of a capacity sufficient for the protection of 100 persons. The dimensions in this case are: length, 6 ft. 7 in.; width, 2 ft. 2¼ in.; height to top of outlet chimney, 6 ft. Here, again, sufficient space should be allowed on either side of the unit for an operator. The price of this is £127 10s., delivered, erected and tested on site.

The filters incorporated in the above units have been found under Government tests to have a life of 800 hours under continuous gas conditions at expected concentrations.

Totally enclosed gear drives, as shown in Fig. 35, are preferable to the bicycle type of drive which, due to maintenance troubles with chains, countershaft bearings, etc., do not stand up so well to long periods of disuse.

KEITH BLACKMAN HOUSEHOLD UNIT

This little plant (illustrated in Fig. 37) will build up a small air pressure in the room and thus prevent any leakage of gas into the shelter through any slight defects in the sealing.

To enable this plant to be put into use, all that is necessary is sufficient small bore light sheet metal, flexible or cast-iron piping to connect the unit to the outside of the gas-proof shelter or dugout, this piping being carried to a reasonable height above the surroundings to prevent the drawing in of air from a possible gas pocket.

The manual power required for a unit arranged to give

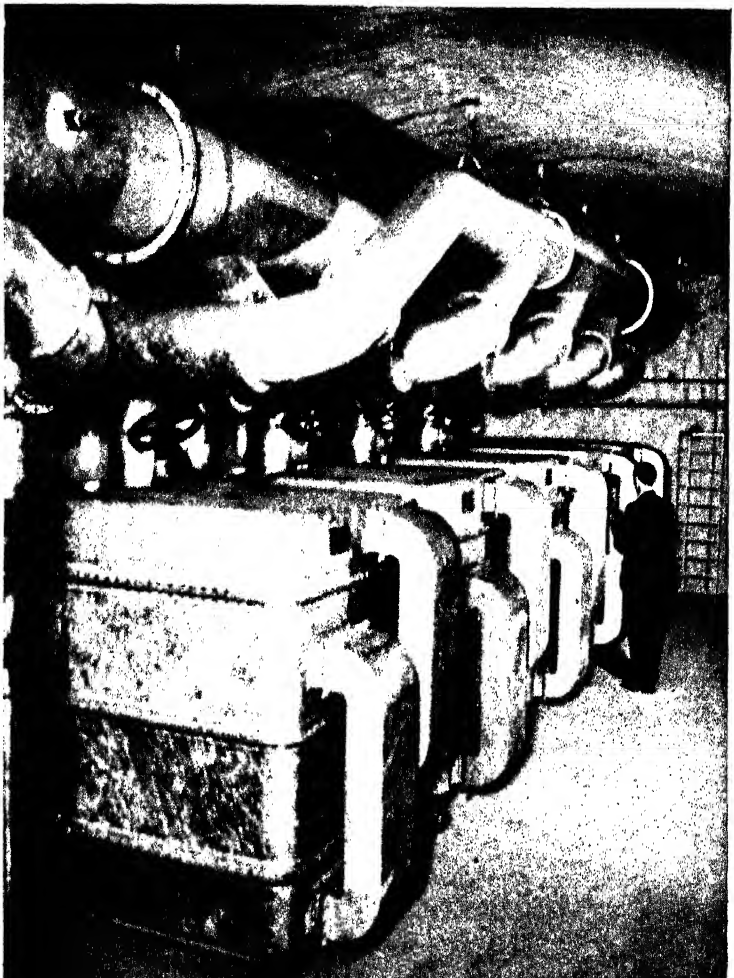


FIG. 36.—Battery of five filters having an output of 350,000 cub. ft. per hour. (Carrier Eng. Co.)

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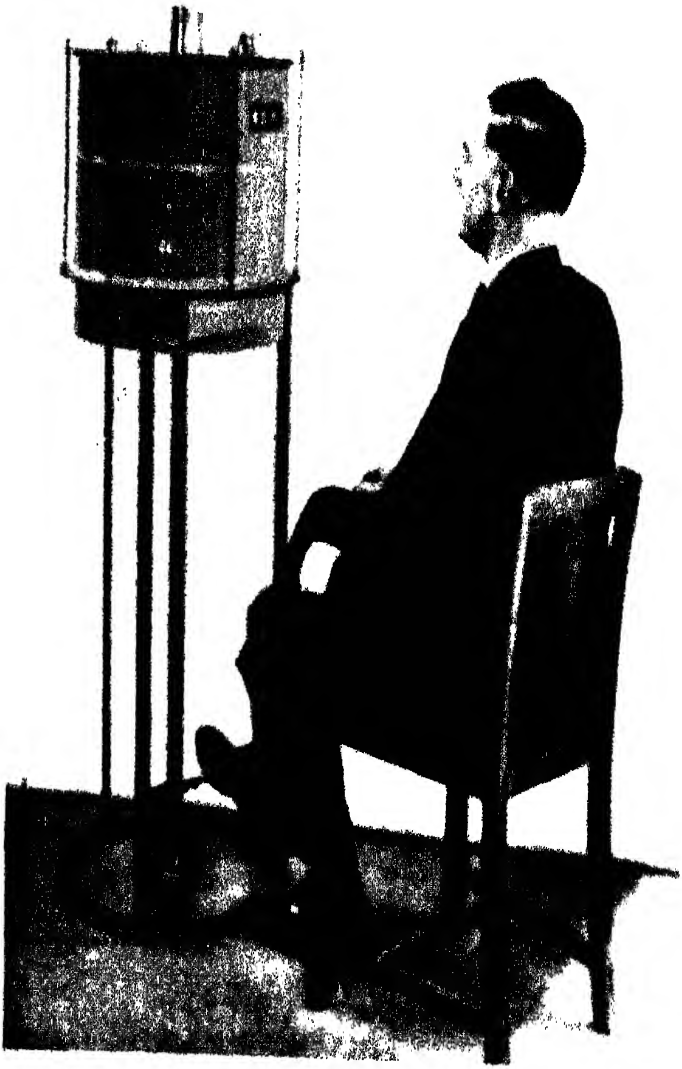

FIG. 17. The Keith Blackman household gas filtration and ventilation unit, suitable for twelve persons.

filtered air to twelve people or the full 120 c.f.m. with filters by-passed is so small as to make electrical gear an unnecessary complication and expense; in fact, the energy required to produce the 30–35 foot strokes per minute on the pedal is so small that a child can provide it continuously in either a standing or sitting position.

Floor space occupied only $2\frac{1}{2}$ sq. ft.

Weight approximately 60 lb. for four persons, 70 lb. for eight persons, 80 lb. for twelve persons.

Quiet in operation, the plant requires almost no attention, due to its running on ball bearings and its springless free-wheel action, which features permit of the set running for five minutes after foot action stops, thus making any necessary change of operators a very simple and unhurried matter.

It is of all-steel construction and is therefore durable and safe at all times.

The filter canisters have been submitted, tested and approved by the Testing Branch of the Home Office; they conform to all their requirements, and similar canisters are embodied in larger filtration plants bearing Home Office official certification mark.

Each filter canister has three stages—a dust pre-filter, an arsenic or smoke filter, and a filter to deal with all known volatile gases.

Each filter unit is capable of giving 800 hours' service in war gas conditions.

The filter canisters can be replaced easily, quickly and cheaply, as necessary.

A gravity controlled by-pass equipment is incorporated in the filter container, the operating rod being provided with a safety gas-tight cap.

This set can be arranged, if particularly required, as a straightforward ventilating plant without any gas filters, but with a small dust filter incorporated. Under these conditions, 120 cub. ft. of air per minute can be delivered with only 30–35 foot strokes per minute.

An air-flow indicator can be fitted to this small unit, if required, at a small extra cost.

Fig. 38 shows a compact mechanical ventilation and filtration unit, which is made by the Sturtevant Engineering Co. Ltd.

Prices of Blackman Household Units.

	£	s.	d.
Size 0/1 for 4 persons	14	10	0
,, 0/2 ,, 8 ,, ...	18	10	0
,, 0/3 ,, 12 ,, ...	22	10	0
Spare filter canister (each) . . .	4	10	0

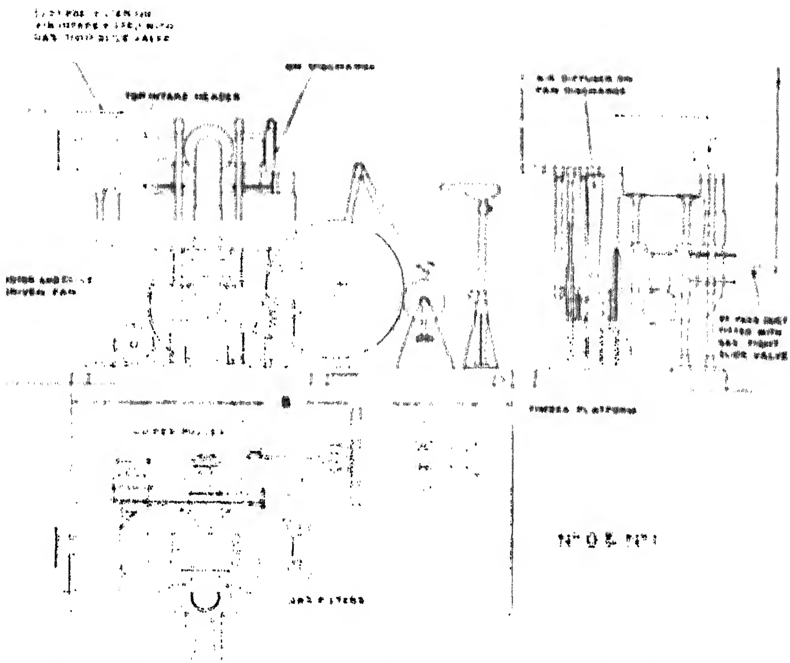

Fig. 39.—Outlines of Sturtevant filter ventilation sets Nos. 0 and 1.

The unit shown in Fig. 38 occupies exceptionally small floor space, but in common with other sets includes :—

A. Air inlet with control sliding valve.

B. Pre-filter to remove coarse dust, such as might be produced by the fall of nearby buildings.

C. Header pipe.

D. Gas filters.

E. Suction header.

F. Centrifugal fan with motor and auxiliary pedal drive.

G. Venturi pipe for measurement of air volume.

H. Gauge for indication of air volume.

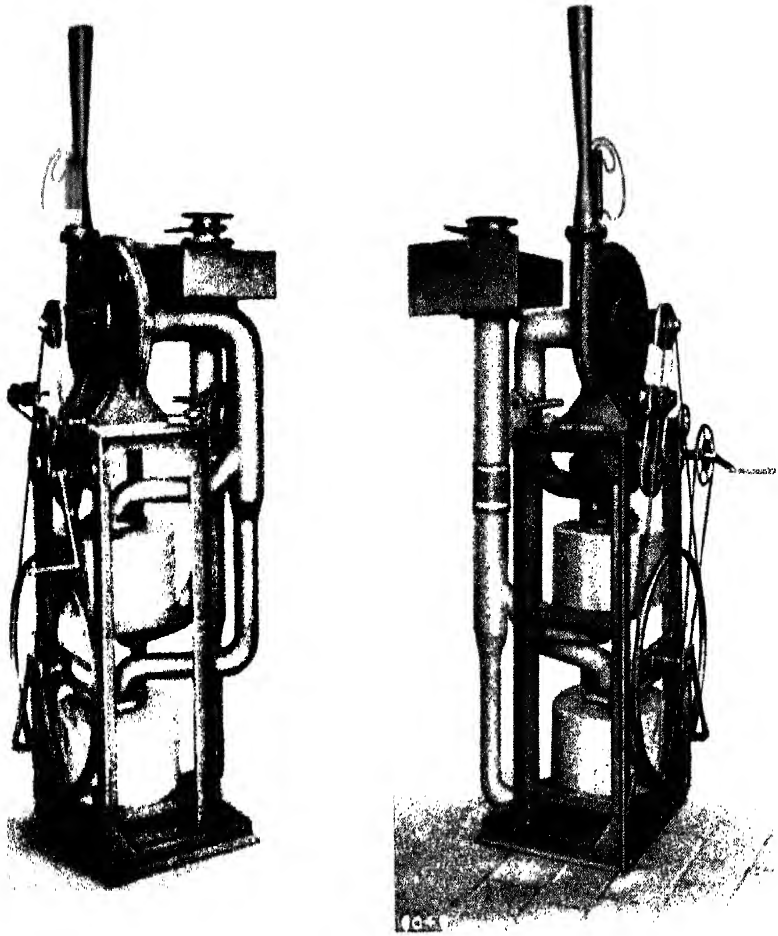

FIG. 48.—Two views of a Sturtevant No. 1 special unit with auxiliary manual drive.

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FIG. [illegible]. German type of electric manual shelter ventilator with gas and smoke filters. Capacities [illegible] of [illegible] cubic ft. per minute.

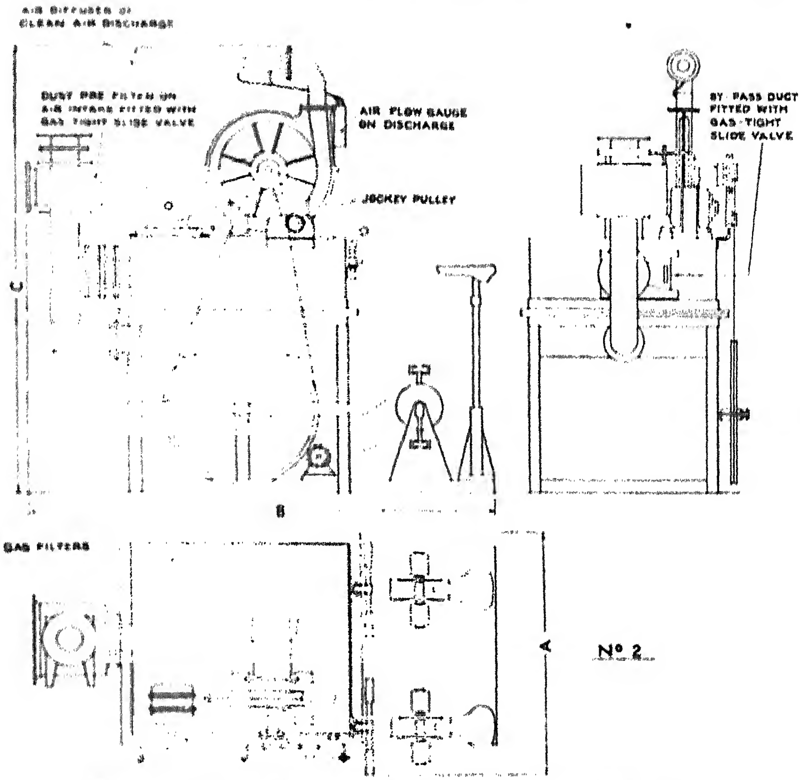


FIG. 40.—Outlines of Sturtevant filter ventilation set No. 2.

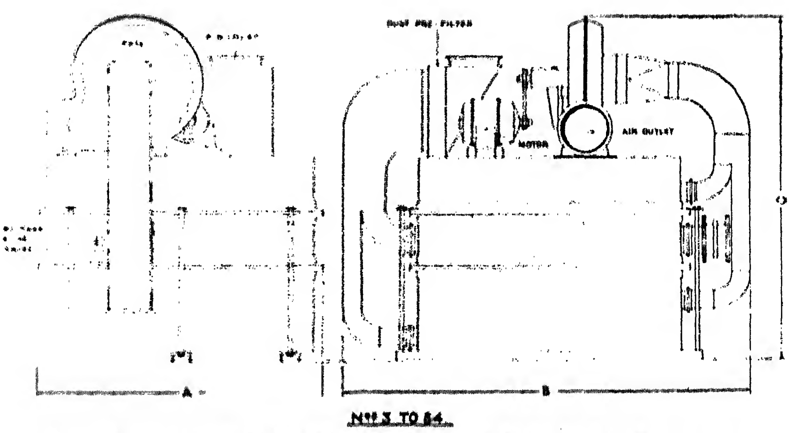


FIG. 41.—Outlines of Sturtevant filter ventilation sets Nos. 3 to 84.

J. By-pass sliding valve to allow air to pass direct to shelter without gas filtration, should conditions of atmosphere permit. (Not fitted in No. 0 unit.)

K. Jockey pulley.

Other Sturtevant sets are illustrated in Figs. 39, 40 and 41, and volumes, overall dimensions and approximate prices are given in the following tables :

Table XLVI
Sturtevant Filtration and Ventilation Units Fitted with Emergency Drive

Unit No.	No. of Persons	Air Volume C.F.M.		Motor H.P.	Size of Ducting		Approximate * Overall Dimensions			Approximate Prices		
		[illegible]	[illegible]		Inlet	Outlet	A	B	C	£	s	d
0	12	30	45	[illegible]	3"	3"	4' 0"	6' 3"	2' 6"	50	0	0
1	25	60	90	[illegible]	4½"	4½"	5' 3"	6' 10"	4' 3"	76	10	0
1A	36	90	135	[illegible]	4½"	4½"	5' 3"	7' 9"	4' 9"	120	0	0
2	50	125	187	[illegible]	6"	6"	5' 3"	6' 6"	6' 3"	125	0	0

* Dimensions in some cases can be altered to suit local conditions.

Table XLVII
Sturtevant Power-driven Units

Unit No.	Number of Persons	Air Volume C.F.M.		Motor H.P.	Size of Ducting		Approximate * Overall Dimensions			Approximate Prices		
		[illegible]	[illegible]		Inlet	Outlet	A	B	C	£	s	d
6	72	180	270	¼	3½"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	96	240	360	¼	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	108	270	405	¼	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	144	360	540	1	6"	9"	4' 6"	7' 3"	4' 4"	Prices for these sets on application. Must necessarily depend upon amount of ducting involved.		
16	192	480	720	1¼	7"	10"	4' 6"	7' 3"	6' 4"			
18	216	540	810	1¼	7½"	11"	3' 6"	7' 3"	5' 4"			
24	288	720	1080	1½	8½"	12"	4' 6"	8' 6"	5' 4"			
27	324	810	1215	1½	9"	13"	4' 6"	7' 3"	5' 4"			
32	384	960	1440	2	10"	15"	4' 6"	7' 3"	6' 4"			
36	432	1080	1620	2¼	11"	15"	4' 6"	8' 10"	6' 4"			
48	576	1440	2160	2¾	11"	16"	4' 6"	8' 10"	6' 4"			
54	648	1620	2420	3	11"	17"	4' 6"	12' 0"	5' 4"			
72	864	2160	3240	3½	13"	24"	4' 6"	12' 0"	6' 4"			
84	1000	2520	3780	5	13"	26"	4' 6"	13' 6"	6' 4"			

* Dimensions in some cases can be altered to suit local conditions.

† This with cycle drive.

Figs. 42 and 43 show the "Evertrusty Degea" shelter ventilator, type MR.1200. The installation takes the form of shelter filters combined with diaphragm pump arranged for manual operation.

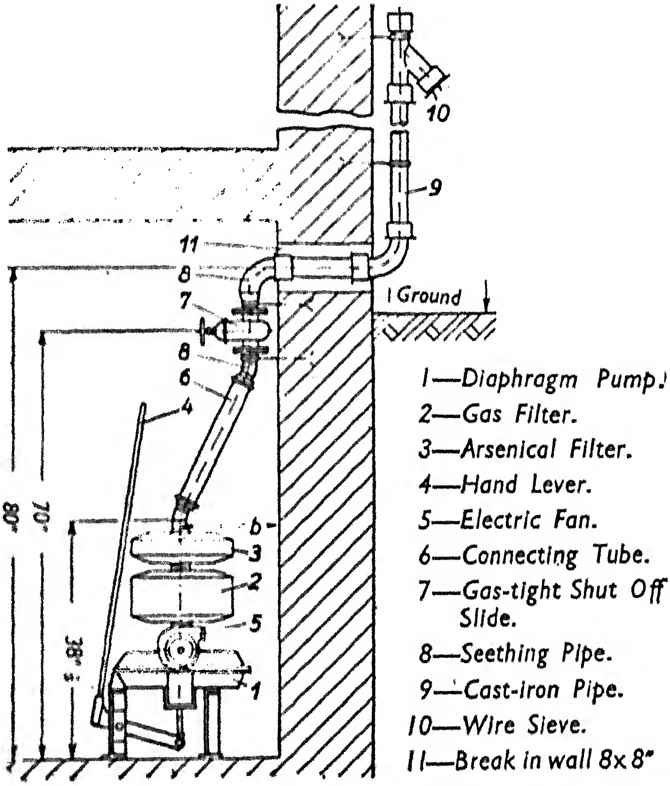


FIG. 43. Over-all dimensions of the filtration unit illustrated in Fig. 42, and having a capacity of 43 cub. ft. per minute.

Shelter Filters

Each unit consists of an arsenical filter and a gas filter, each of these filters being contained in a separate cylinder fitted with standard connecting threads. The cylinders are screwed together, so that each one can be changed independently, and the operation is facilitated by a flexible connecting tube in addition to a shut-off slide in the suction system which remains shut during the renewal. Shelter filters have been standardised

for the provision of definite air supplies. A special part may be inserted between the diaphragm pump and the suction system to enable the apparatus to be used for ordinary peace time ventilating purposes.

Diaphragm Pumps

These have proved especially reliable and suitable for the provision of air to Air Raid Shelters. The interior of the pump houses a circular piston, which can be moved up or down by a hand lever. The outer edge of the piston is connected with the housing by a circular leather diaphragm. If the lever is moved away from the operator the piston rises, and the air over it percolates through a valve into the air raid shelter.

At the same time the shelter receives a new supply of purified air, which is drawn from outside through the filter and the channel lying underneath the piston. If the lever is moved towards the operator this operation is reversed.

When the hand level is worked at the rate of thirty-five strokes per minute, the following results will be obtained :—

TABLE XLVIII

Results.	Shelter Ventilator Type		
	MR 600.	MR 1200	MR 2400
Air supply obtained (in litres per minute) .	600	1,200	2,400
Cubic feet per minute	22	43	86

The number of strokes can easily be controlled by a pendulum which works at a rate of thirty five strokes per minute and which can be hung up on the wall. All ventilators can be worked either by hand or by electric drive. One person is usually sufficient to work the ventilators by hand, but Type MR.2400 has a special hand level so that two can work it. So long as current is available, the electric blower attached to the ventilator will provide the air supply. The electric blowers are fitted with universal motors, and are simply plugged into the electricity supply. They can subsequently be attached to the ventilators if necessary.

Construction

The suction conduit line is best constructed about 9 ft. to 30 ft. above the ground, the inlet aperture being suitably protected against dirt and rain. It is recommended that a draining pipe and a gastight shut-off valve be incorporated in the suction conduit immediately above the filter. Cast-iron piping should be used for the open-air section, as, although this will crack when hit by bomb splinters, it invariably leaves a cross-section free. On the other hand, wrought-iron piping may easily be completely crushed.

Distributing conduits will generally only be necessary when one ventilator is to supply several adjoining shelters.

TABLE XLIX

PARTICULARS

Apparatus.		Weight.			Price, each.		
		cwt.	qr.	lb.	£	s.	d.
SHELTER VENTILATOR, TYPE MR.600 Air capacity, 22 cub. ft. per minute, consisting of diaphragm pump with attached shelter filter for hand operation	148		2	24	35	10	0
SHELTER VENTILATOR, TYPE MR.600 Exactly as specified above, but with electric blower (universal motor, 110 or 220 volts) for working either by hand or electrically.	149	1	3	12	41	15	0
SHELTER VENTILATOR, TYPE MR.1200 Air capacity, 44 cub. ft. per minute, consisting of diaphragm pump with attached shelter filter for hand operation	1150				50	0	0
SHELTER VENTILATOR, TYPE MR.1200 Exactly as specified above, but with electric blower (universal motor, 110 or 220 volts) for working either by hand or electrically .	1160	2	1	24	56	10	0
SHELTER VENTILATOR, TYPE MR.2400 Air capacity, 88 cub. ft. per minute, consisting of diaphragm pump with attached shelter filter for hand operation	1250	4	1	25	86	10	0
SHELTER VENTILATOR, TYPE MR.2400 Exactly as specified above, but with electric blower (universal motor, 110 or 220 volts) for working either by hand or electrically .	1260	4	2	21	99	15	0
Connecting hose, including hose clips . .	—				1	1	0
Excess pressure and exhaust valve . .	Um24				3	10	0

Direct ventilation of the emergency toilets and air locks is not necessary. It is recommended that the used shelter air be expelled through these rooms. Should it be necessary to ventilate a series of rooms, it would be more convenient to use a centralised ventilating installation, but in order to carry this into effect a supply of current must be available to drive the electric ventilators and shelter filters.

" Y.A.Y." gas filtration and ventilation units are available at the prices given below :—

TABLE I.

Capacity of Electro-Manual Plant C.f.m.	Capacity of Shelter People.	Cost, Delivered (but not Installed)	[illegible]	[illegible]
		£	£ s. d.	
50	20	88	4 8 0	
125	50	114	2 5 7	
150	60	126	2 2 0	
250	100	165	1 13 0	
400	160	220	1 7 6	
500	200	258	1 5 10	
750	300	352	1 3 6	

October 1st, 1938.

Young, Austen and Young Ltd.,
12 Buckingham Street, W.C.2.

A cheap form of air purifier for use in conjunction with vacuum cleaners is now available. This is known as the Conjoint Air Purifier and is cylindrical in shape, the dimensions being 7 in. diameter and 13½ in. high. There are three nozzles to the air purifier, one for the inflow, one at the front below for the purified air while the one at the front above is for the by-pass for uncontaminated air.

As long as there is no contamination of the atmosphere around a building there is no need to pass the air through the purifier, and, therefore, each purifier is provided with a by-pass, which can be screwed down and closed as soon as contamination is likely. The flexible tube attached to the Suction Unit is connected to the front of the Air Purifier. To use the by-pass

it is only necessary to unscrew the cap and slip on the rubber connector or tube. The by-pass must be screwed down tightly after detachment of suction tube.

The Air Purifier Cylinder contains two cartridges—A and B—the cartridge A contains activated carbons, and other elements. Cartridge B contains the Asbestos elements specially treated and carded, cotton wool impregnated with a chemical compound and a 16-member absorbent corrugated paper filter pad. Refills are available.

Connected to vacuum cleaners by a suction hose the air purifiers may be attached to a door leading to a shelter or to the cover of a fireplace from which the supply of fresh air is drawn down the chimney.

One Air Purifier will provide 1,000 cub. ft. of purified air per hour.

Prices are below.

TABLE LI

	£	s.	d.
CONJOINT AIR PURIFIER	2	17	6
Complete with Cartridges A and B. Unmounted but with fixing lugs.			
FIREPLACE UNIT.	3	19	6
Air purifier, mounted on plywood panel with rubberised fabric apron to fit average fireplace.			
DOORWAY UNIT	6	15	0
Air purifier and Sears' single pneumatic air lock.			

Manual Filtration and Ventilation

A type of manually-operated filter and ventilator is shown in Fig. 44. The advantage of this type is its positive action, simplicity and ease of operation.

An electro-manual filter and fan, made by Mellor, Bromley & Co. Ltd., suitable for a room housing twenty-five people costs £50 complete *ex* works.

Space does not permit of the inclusion of particulars of all the makes of ventilation and filtration plant now available, but those illustrated are thought to be typical.

No comparisons are made or intended, and the prices are given only for the convenience of the reader.

In comparing gas filtration and ventilation plants, due regard must be paid to the size of the filter and the duration of its effectiveness in use as well as its capacity to filter smokes and the installed cost per person.

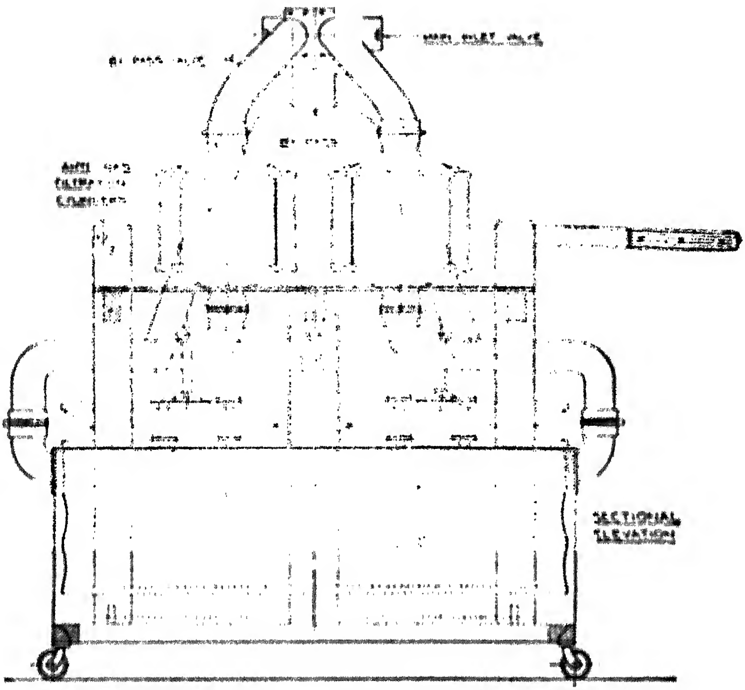


Fig. 33. [illegible] No. 3 air-purifier manual for shelters, etc. (capacity 8,000 c.f.m.), suitable for continuous use by 52 persons. The pressure on the lever is 28½ lb. and one man applying 40 strokes per minute can deliver 8,000 c.f.m. It has two gas-tight valves, the first a shut-off valve for the main inlet on the contaminated side of the filters and the second a by-pass valve for use as long as the air remains uncontaminated.

The installation of a ventilation system increases the capacity of a refuge and often results in a reduction in the "all in" cost per person.

KONTRAGAS EMERGENCY EQUIPMENT

Recognising the difficulty of making any building completely gas-proof and also in order to overcome the defects which would

be caused in ordinary buildings by vibration and blast, the Kontragas Company Limited have evolved a shelter in the form of a tent which can be slung from the walls or ceiling of the room in order to give complete isolation from all known forms of poison gas.

This tent is manufactured from tested, translucent material similar in all essentials to the material used in the manufacture of gas proof suits, and all the seams are hermetically sealed. It is completely gastight, and the only means of entry is provided by an opening in the base sheet, which can be quickly sealed from the inside. The tent when collapsed for storage purposes occupies quite a small space, but when erected encloses from 1,000 cub. ft. of air upwards, according to size. It is simply and easily suspended from the roof or ceiling, and hangs down to floor level in loose folds, taking up its natural shape. Being thus loosely suspended, it is at once immune from damage by concussion, and owing to its special light construction, it may be easily slung by one person.

Such tents may be used in the ordinary house or office, hospitals, ambulances, lorries, trams, cellars, etc., or slung under marquees or tents in an emergency. They are also useful in decontamination and cleansing centres.

The air within the hermetically sealed closure would normally soon become polluted were not some special form of ventilation and filtration introduced or a regenerator installed.

The "Kontragas" Regenerator

The air regenerator has been evolved after considerable research, and no power or manual operation is necessary, neither is it dependent upon gas cylinders nor other expensive and unwieldy apparatus. By the simple expedient of adding "air salts" (an accurate measure of specially prepared chemicals) to water, the necessary amount of pure oxygen is automatically supplied to the interior of the tent, and simultaneously the carbonic acid gas given off by respiration is absorbed. In addition, hydrogen peroxide is freely liberated, which acts as an exceedingly efficient steriliser. This simple apparatus will supply a normal atmosphere for any given time, according to the amount of "air salt" available.

For the smaller domestic tent, capable of accommodating a

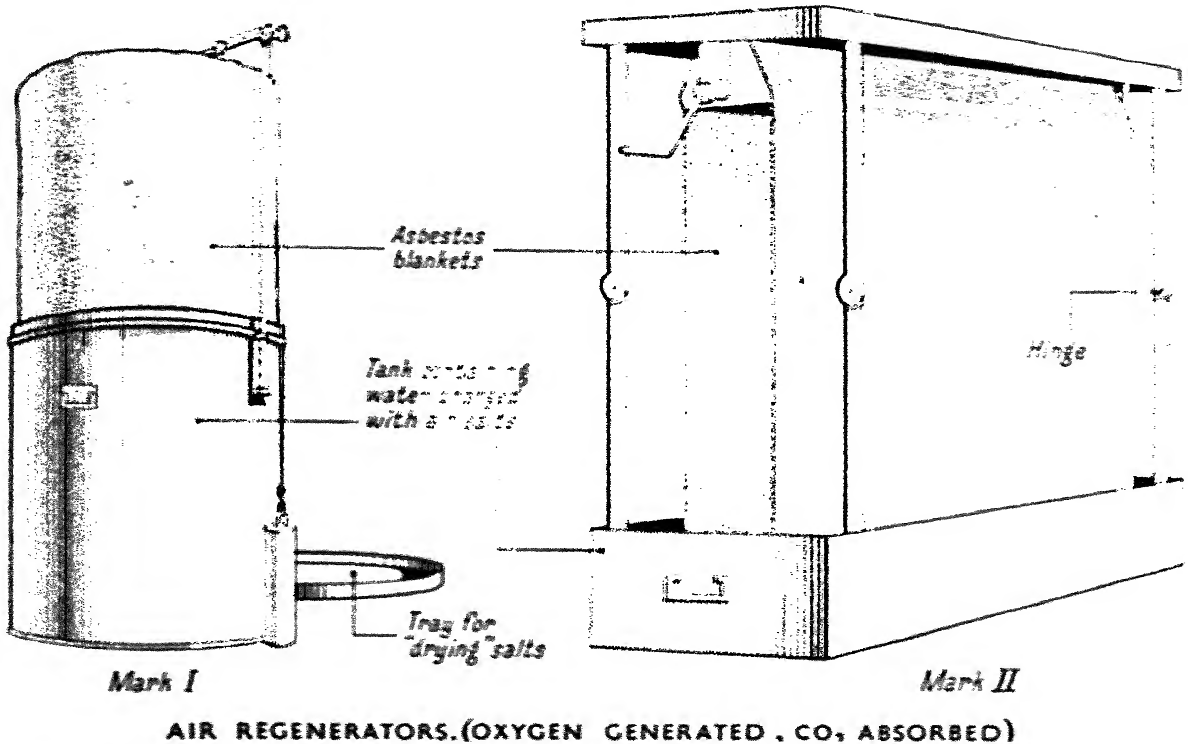


FIG. 45.—"Kontragas" air regenerators. Mark I, suitable for 6 people. Mark II, suitable for 12 people.

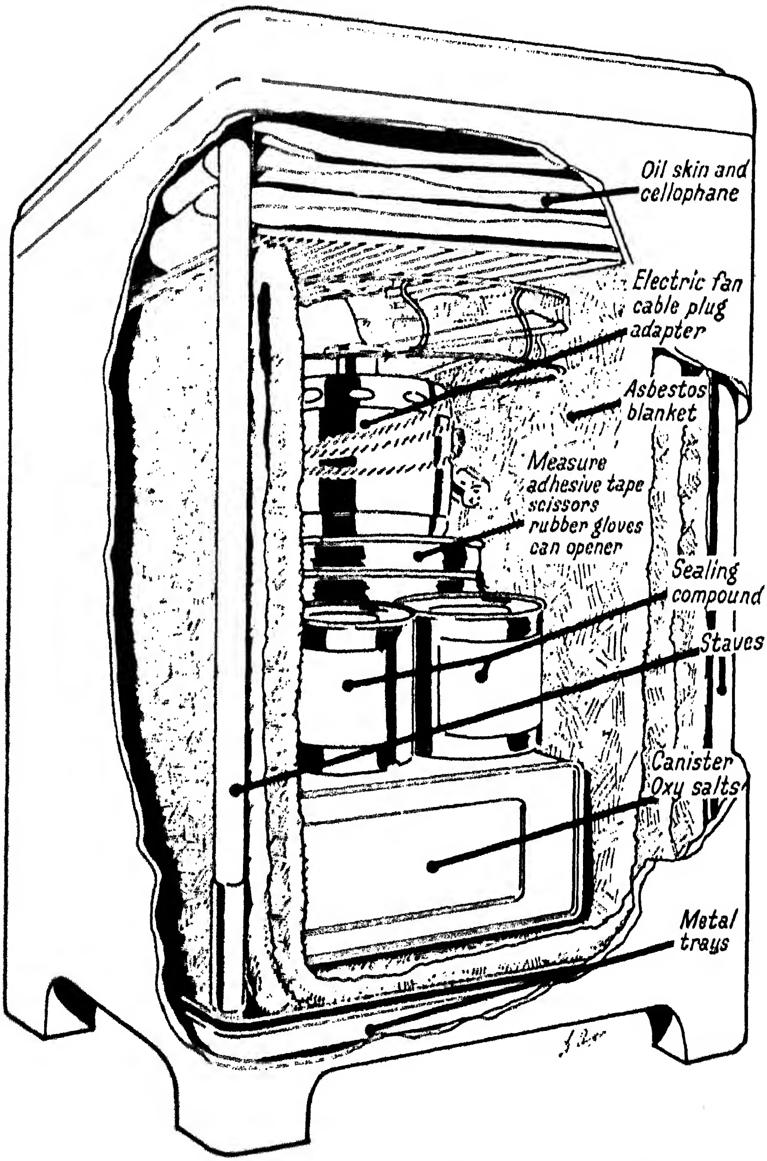


FIG. 46.—"Kontragas" bathroom gas-proofing outfit and air regeneration equipment all accommodated in bathroom stool.

family of five, only twenty "air salt" packets are required for a continuous "stay-in" of twelve hours, if such a long period of sheltering should prove necessary.

Mark 1 regenerator, shown in Fig. 45, is suitable for six people and the cost is £8 *ex* works.

Mark 2, suitable for twelve people, also shown in the above-mentioned Fig., is £12 *ex* works.

"Air salts" are 1s. 6*d*. per lb. 1 lb. tin being sufficient for three persons for one hour.

A Kontragas tent 8 × 8 × 7 ft., complete with Mark 1 regenerator, can be purchased for £30, and a 12 × 12 × 7 ft. tent, complete with Mark 2 regenerator, can be purchased for £45.

To meet the demand for equipment suitable for temporary use in houses without the tent a bathroom outfit, generally as shown in Fig. 46, is available at £8. This contains all the necessary material for the gas-proofing of the bathroom, and the necessary chemicals, blankets and other apparatus, as described for use in conjunction with water placed in the bath for the purpose.

This outfit is suitable for five adults or three adults and four children, for many hours continuous operation.

One pound air salts generates 3 cub. ft. of oxygen, and the caustic soda produced is sufficient to absorb 2 lb. of CO_2. The "air balance" is preserved with no measurable change in pressure—if anything a slight plenum is produced of the order of 3 cub. ft. added to 1,000. ; 1 lb. is sufficient to produce air regeneration for three persons for one hour, or one person for three hours ; two children under eight years counting as one adult.

In the tent, with ten people present, 1 lb. of air salts needs to be added every twenty minutes.

Note. A man at rest uses about 0·7 cub. ft. of oxygen per hour and produces about 0·6 cub. ft. of CO_2.

TYPICAL TESTS

Carried out by L. H. Kent, Esq., at works of Messrs. George Kent Ltd.

Report on Air Conditions during Test of A.R.P. Shelter

Test Carried out on Thursday, July 13th, 1939, 2.5 p.m.

Size of shelter . . .	7 ft. 3 in. high, 9 ft. wide, 20 ft. 7 in. long.
Number of persons in shelter .	50.
Surface area per person .	16·1 sq. ft.
Cubic capacity per person .	26·9 cub. ft.
Walls	Whitewashed concrete. Ceiling 15 ft. below ground level.

Test 1

All outlets sealed, pump not working, *i.e.*, no air entering at all. Duration of test decided by comfort of occupants.

Table LII

Time. Mins.	Temperature °F.	Carbon Dioxide in Air per cent.	Humidity. Per cent.
0	65·5	0·078	62
10	72	0·396	63·5
20	74·5	0·470	64
30	75·7	0·910	65·5
40	77	1·455	67
50	77·5	1·991	69
54	80	2·090	69

Notes

Time taken from the instant all occupants were within the shelter.

Doors were sealed six and a half minutes later.

Temperature taken near one end further from door and 4 ft. 6 in. from floor.

Final temperature was taken at the geometric centre of the shelter.

Pressure remained just above atmospheric value.

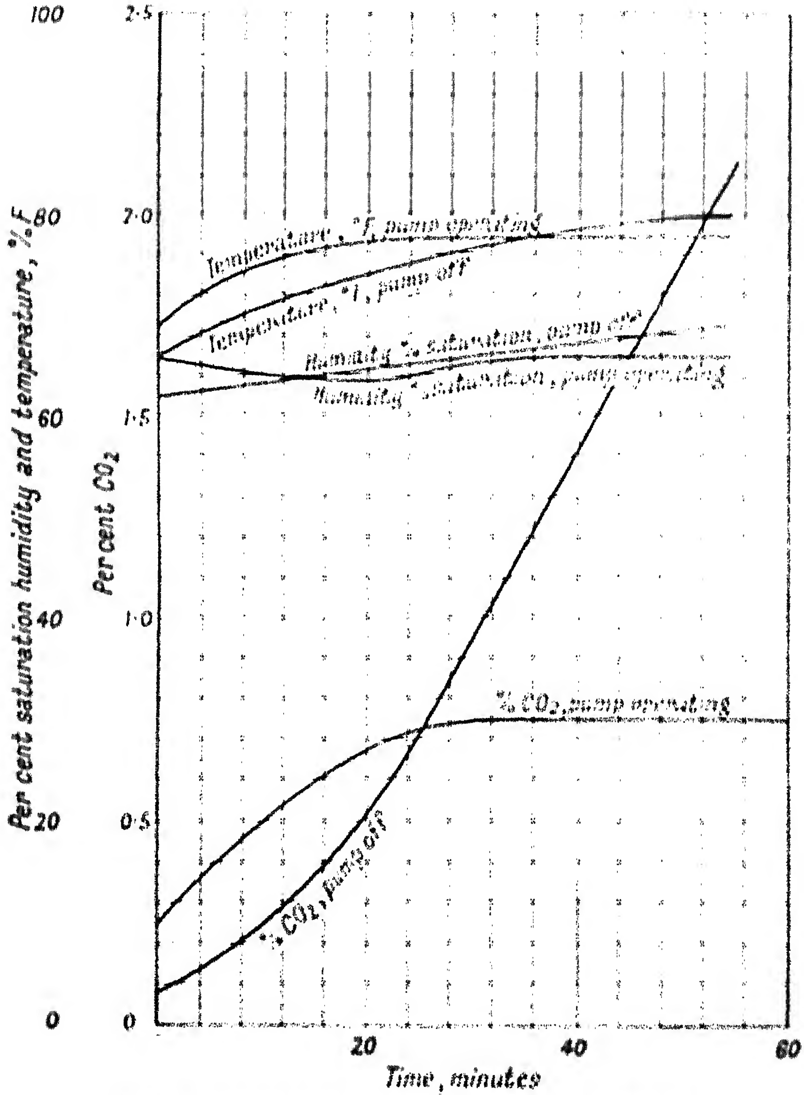


FIG. 47.—Graph showing results of test on air in shelter.

Test 2

All outlets sealed, hand pump worked at average of thirty turns per minute, equivalent to approximately 120 cub. ft. of air per minute drawn in from outside.

TABLE LIII

Time. Mins.	Temperature at Far End.	Temperature at Near End. (Near Entrance.)	Pressure Difference. W.G. in.	Carbon Dioxide. Per cent.	Humidity. Per cent.
0	69	70	0	0·253	66
10	76	75	$\frac{1}{8}$	—	63·5
20	76·5	76	$\frac{5}{8}$	—	64
30	77·5	76	1	0·743	65
40	77·5	76	1 (1)	—	66
50	78	76	$\frac{1}{2}$	—	65·5
60	78	76	$\frac{1}{2}$	0·765	66
70	78	76	$\frac{1}{2}$	—	66
81	78	76	$\frac{1}{2}$	0·743	70 (2)

(1) Rise in internal pressure reduced by cracking open sealed gas door.
(2) Sharp rise in humidity due to pump stopping.

The observed results are shown in Fig. 47.

Conclusion

At the end of Test 1 only one occupant complained of any discomfort, and it was found that he was suffering from indigestion! It was generally agreed by the rest that conditions would remain tolerable at least up to one hour.

Test 2 shows that conditions reach equilibrium values after about half an hour. It should be possible to remain in the shelter several hours with the pump working and all outlets closed so long as internal pressure is not allowed to rise too much.

Natural Ventilation

Except when gas is about, reliance can be placed on natural ventilation of shelters, provided the arrangement of doors and exits makes cross-ventilation possible or the use of protected low level inlets and high level outlets induces ventilation by means of convection or "stack action."

Adequate natural ventilation should in every case be provided in shelters, irrespective of the installation of a gas filtration plant, because the continuous air change ensures habitable shelters all the time.

An extractor of the Greenwood "Vacaire" type commences

to extract vitiated air in the lightest breeze and continues to operate in winds of any velocity.

A fresh air intake brought through a weathered inlet at high level terminating in a gas valve at low level in the shelter completes the system.

Gas-tight valves, which may be instantly closed by a slight twist of the control handle, should be fitted on the inlets and outlets in the shelter.

To promote air circulation the extract pipe should commence high up near the entrance or air lock and the intake low down at the opposite end.

The Greenwood-Airvac system, with 6 ft. lengths of 4 in. galvanised steel piping costs £5 5s., and Mark 88, with 8 in. super extractor for fifty persons, £25 10s.

Equipment

Permanent equipment in Air Raid Shelters must be adjusted to the requirements of each case. The equipment of large communal shelters is dealt with in Chapter X., but the minimum contents for the smaller domestic shelter are enumerated below and depicted in Fig. 25.

The cost of the minimum equipment for the gas-proof refuge room would in the majority of cases be much less than the above estimate, owing to the fact that the masks issued free by the authorities would in all probability be utilised and furniture and domestic utensils used.

The cost per person ought not in these circumstances to be more than a few shillings.

In addition to the above necessities, the following would add to the convenience and comfort in the refuge room :—

Telephone—for vitally urgent calls only. The service in a raid will be overloaded with official business and may also be damaged.

Wireless—small battery operated type—electric light service might fail. Philco supply a suitable set.

Fire Extinguisher—or hand pump for water and dark glasses for fire fighting.

Pets requisites—such as dog basket and ash box, parrot cage, etc.

Table LIV

Minimum Equipment for Emergency Refuge Room.

Article.	Cost if new or not issued. £ s. d.	Cost per person on basis of five persons. £ s. d.
1. *A roll call list* of all who should be present	—	—
2. *Gas masks* for all occupants (5) with name of each on containers	4 7 6	0 17 6
Five spare filters	1 2 6	0 4 6
Five spare containers	0 12 6	0 2 6
3. Water in covered receptacle for drinking, washing, gas blankets, etc.	0 10 0	0 2 0
4. Food in airtight tins or jars, tinned foods, containers	1 0 0	0 4 0
Tin opener and corkscrew	0 0 6	0 0 1½
5. Tables, chairs and benches	5 0 0	1 0 0
6. Two mattresses; Five blankets	3 0 0	0 12 0
7. Plates, cups, knives, forks, etc.	0 10 0	0 2 0
8. Basin for washing, soap and towels	0 2 6	0 0 6
9. Chamber pots, toilet paper, disinfectant and screen for privacy	0 10 0	0 2 0
10. First-aid outfit	1 0 0	0 4 0
11. Box of sand with shovel; Dark glasses	0 2 6	0 0 6
12. Emergency lighting, electric torches	0 5 0	0 1 0
13. Means of repairing gas-proofing if damaged. Paper pulp, spare blanket, tools, gummed paper, paste, varnish, etc.	1 0 0	0 4 0
14. One set—gum boots, mackintosh, cap, protective gloves, etc., for reconnoitring.	1 10 0	0 6 0
15. Tray of bleaching powder for decontamination, spare buckets, etc.	0 5 0	0 1 0
16. Means of occupying the time, without exertion, books, playing cards, toys, say	1 0 0	0 4 0
17. Pickaxe, crowbar, etc.	1 0 0	0 4 0
Totals	£22 18 0	£4 11 7½

Homely furnishings—rest quietly and conserve the oxygen, and do not smoke or light candles or lamp.

Carry on as far as possible with your ordinary civil occupation and thus minimise the effectiveness of the raid.

Before repairing to the shelter shut all windows and doors in the rest of the building, put out all fires and turn off the gas at the meter. All lights should be switched off except in the shelter.

Fig. 25 shows the interior of a 10 ft. by 10 ft. by 8 ft. refuge

room suitable for five persons for twelve hours' continuous occupation and most of the necessities and other requirements.

Regarding the pets, see Chapter XIII.

Plans

The numerous figures already referred to indicate various methods of dealing with a variety of problems associated with the gas proofing of a shelter, but Fig. 24 shows the probable work to be done on an ordinary 10 ft. by 10 ft. by 8 ft. room accommodating five persons for twelve hours.

Specifications

The specification of work required to be done in gas proofing must necessarily be drawn up to suit the specific requirements of the case.

The following are, however, broad requirements which should be specified as a general rule :—

1. The shelter must, in an approved manner, be rendered proof against blast pressure of a 500 lb. H.E. bomb exploding not less than 50 ft. away.

2. The shelter must be rendered proof against the penetration of splinters from a 500 lb. H.E. bomb exploding not less than 50 ft. away.

3. The shelter must be rendered safe against the penetration of a 25 lb. incendiary bomb in direct impact.

4. The shelter must be strengthened structurally as necessary to enable the roof to sustain the impact and weight of *débris* of the building falling down.

5. The shelter must be gas-proofed to such a degree that the smell of amyl acetate imparted to the air on all sides and over the top of it (by waving a cloth partially soaked with this material through the air) does not penetrate to the interior in under thirty minutes. When possible, the advice of an expert should be sought and the work specified to be carried out to his satisfaction.

Cost Data

Cost data for equipment and filters and ventilators have already been given. The cost of structural work and gas-proofing will necessarily depend upon the specific requirements,

TABLE LV

	Materials only.			Estimated Contract Price.		
	£	s.	d.	£	s.	d.
1. FIRE PROTECTION Take up floor covering over ceiling of refuge, lay down 120 sq. ft. of 3 DF2 Durasteel flat sheet ⅜ in. thick and replace covering .	9	10	0	11	10	0
2. SPLINTER PROTECTION Construct sandbagged splinter protection in garden outside refuge 17 × 8 ft. high × 3 ft. thick av. (400 bags)	4	0	0	7	0	0
3. Take up floor boards and strengthen joists with additional support on bricks in cement mortar wedged up with slate . Under new struts and sand boxes (21 places 10 bricks each)	1	12	8	3	1	6
4. Provide 57 packing cases 2 ft. cube and fill with sand or dry earth and packed close and 3 courses high	5	0	0	22	4	0
5. Provide and fix new timber strutting to ceiling as shown in Fig. 24, including wedges and 8 dogs	2	16	6	3	11	6
6. GAS PROOFING Provide and fix four blankets for air locks with all battens and nails . . .	2	0	0	2	18	0
7. Wedge up window, putty up cracks and protect glass with cellophane (16 sq. ft.) .	0	3	0	0	8	0
8. Provide and fix blanket on wire netting on strong frame over windows (26 sq. ft.) .	1	0	0	2	10	0
9. Seal floor cracks as described . . .	0	2	0	0	10	0
10. Make good wall and ceiling plaster as described	0	2	0	0	15	0
11. Seal up two doors as described . . .	0	2	0	1	0	0
12. Block up chimney with sandbag, rags and plaster. Seal fireplace with metal-faced plywood and frame as described . .	0	6	0	0	15	0
13. Block up ventilator twice paper and varnish (9 × 6 in.)	0	0	6	0	2	0
Total estimated cost of materials only for works shown on Fig. 24	26	14	8			
Total estimated cost of work shown on Fig. 24; materials, labour and contractor's profit				56	5	0

It will be seen that on the basis of the work being carried out by volunteer labour, the costs per person work out as below :—

	£	s.	d.
Fireproofing	1	18	0
Splinter protection	2	13	10
Gas proofing	0	15	1
Total	£5	6	11

As a rough guide, however, the estimated cost of the whole of the work indicated on Fig. 24 is given in Table LV. The prices given are based upon those ruling in the London district late in 1939 and include contractor's profit.

If the work is carried out entirely by volunteer labour, the work naturally would cost much less and would be limited to the cost of materials only.

The room in question is 10 ft. by 10 ft. on plan 8 ft. high on the ground floor of a two-storey house, assumed to have one window, 6 ft. 6 in. by 2 ft. 6 in., and two doors of the same dimension, one fireplace, a ventilator, 9 in. by 6 in., and a ceiling that supports an upper floor, and that needs strengthening as shown.

The average amount of structural defects which would usually be met with in practice has been assumed.

ANTI-GAS COATINGS

It is claimed that Vigorised paints and coatings have, beside their unique application features (viz. wet-on-wet at short intervals between coats), shown after prolonged tests to possess highly valuable resistant properties to mustard gas, and its recognised decontamination process.

The action of the gas is such that in its liquid state it is quickly absorbed by the majority of painted surfaces, which by virtue of this absorption can become a dangerous source of future contamination. Further, the decontamination processes necessary to successfully neutralise contamination is of a rather drastic character, which can chemically destroy, or seriously weaken painted surfaces, and it is on this account that Vigorised media have been developed along lines which have made them resistant to both the gas itself and the chemically destructive action of decontamination solution. Vigorised anti-gas coatings can be supplied for all kinds of decorative finishes and for the impregnation and proofing of fabrics for anti-gas clothing, etc., etc.

Tests have shown that two hours' immersion of Vigorised anti-gas medium in liquid mustard gas leaves a surface which can readily be decontaminated by the recognised and standard methods without detriment. The prices are 15s 6*d*. per gallon for interior use and for exterior use, undercoating 18s. per gallon

and finishing 21*s*. per gallon. The covering capacity is 80 sq. yards to the gallon, and all colours can be obtained from the manufacturers, Messrs. Pinchin, Johnson & Co. Ltd.

SANITATION FOR AIR RAID SHELTERS

In view of the high degree of humidity likely to be caused by relatively large numbers of people remaining for a period of time in a confined space, and the resultant enervation of the atmosphere, no sewage, either solid or liquid, must be allowed to remain exposed to the air. Sanitary units should therefore be either water-closets or chemical closets of an approved type; latrine buckets or other makeshifts are *not* satisfactory for numbers of people.

Water-closets rely for their efficiency on a continuous supply of water, and in view of the possible curtailment of this during an air raid, owing to lack of pressure in the mains, there should wherever possible be chemical closets in reserve, particularly for first-aid posts and other key points.

It is very desirable that both water-closets and chemical closets intended for use during an air raid should be fitted with BAKELITE SEATS, as these being completely non-porous can be very easily decontaminated and/or cleaned after an emergency, whereas wooden seats would have to be scrapped if contaminated and are much more difficult to clean if they become fouled.

In selecting a system of chemical sanitation it is very important to ascertain that it is efficient *without* the fitting of a ventilation pipe to each closet as this is seldom practical. Some systems employ a chemical of a caustic nature which produces ammonia and other gases upon contact with sewage, and are therefore not suitable for use in a confined space without individual ventilation of each closet. The type of chemical closet recommended is that in which the chemical is of a *germicidal* rather than a destructive character and incorporates a sealing element, which prevents solid sewage from becoming partly exposed to the air during sterilisation. There is no objection to emptying such closets down a W.C. or manhole after the emergency.

In calculating the number of sanitary units required it should be borne in mind that their use will be greater than normally,

and therefore the maximum number possible should be provided. It is suggested that one closet to every fifteen people of each sex is a suitable ratio to aim at, and that 1 : 20 should be regarded as the minimum in normal circumstances. 1 : 25 is called for under the regulations.

Leading sanitary authorities have for many years approved the installation of chemical sewage treatment processes for use in localities where main drainage and water supply are not available.

Such a system is ideally suitable for Air Raid Shelters, and the Elsan conveniences, guaranteed odourless and hygienic, are entirely self-contained, compact, neat and sanitary. Over thirty different models are available, but models most generally adopted for Air Raid Shelters are Elsan patterns, Nos. 33, 44 and 45.

Where it is not convenient to erect the ventilation pipe, a cap is supplied for the vent. connection, and a SPECIAL ELSANOL used, which ensures an odourless and hygienic service—even without the use of the vent. pipes. Prices for these being :—

			£	s.	d.	
Model No.	33.	Without vent. pipes	2	10	0	each.
,,	44.	,, ,, ,,	4	0	0	,,
,,	55.	,, ,, ,,	5	10	0	,,

Two charges of chemical are supplied free with each model. Further supplies cost 5s. per gallon (1 gallon being sufficient for eight charges).

The approximate sizes of each unit are as below :—

No.	33.	14½ × 16 × 18½	in.	high.
,,	44.	15½ × 19½ × 18½	in.	,,
,,	55.	15½ × 19 × 19½	in.	,,

The Austral Cabinet Co. Ltd., of 15 King Street, S.W.1. have perfected a system for treating both excreta and urine in a strong alkaline solution "Austranol," which delivers both, in fluid form, fit to go into the earth by a soak away, or to a river or the sea, in a condition free from any living bacilli, even when typhus and cholera bacteria have been known to be present in the fæces.

The Cabinet consists of a steel tank half filled with the

solution of "Austranol." This is of a special petal type, notable for the rapidity with which it dissolves. The essential feature of the Cabinet is a tray provided with a mechanism which causes it to rise or fall according to the raising or lowering of the lid. Thus, after the Cabinet has been used, the lowering of the lid subjects the tray to a quick immersion in the "Austranol" solution. Owing to its design, a flushing action is set up which washes the excreta clear of the tray into the solution, where it is *consumed* and sterilised by the chemical.

The mechanism itself, which is common to all models, has the advantage that it is simple and foolproof. A system of levers analogous to a link motion allows the rods attaching the tray to the lever extending over the seat cover to move in a perfectly vertical line, and flushing is accomplished without effort and with the minimum of friction in the mechanical parts.

The Cabinet is made in numerous models, one of which, Type "C" it is suggested, would be the most suitable where ease in emptying is important. It is equipped with a plunger contained inside the Cabinet, by which a sump plug at the base of the tank is withdrawn. This model takes 135 uses at one charge.

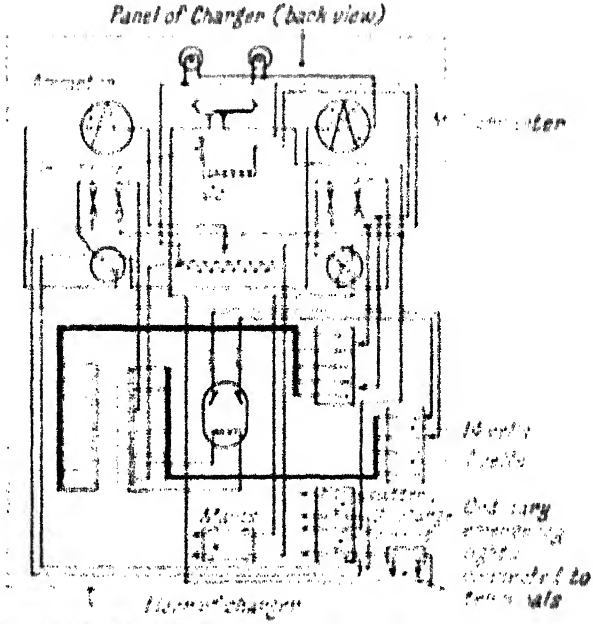
Model "B" is much as the former, but takes 275 uses at one charge and is still portable. Battery Model is three seats on one body, taking over 600 uses, and is used in ships, camps and factories as well as recreation grounds, etc.

The Urine Sterilising Tank passes contents to the same soak-away or storage tank as that used for the Cabinets, in a state of complete sterility. It is suitable for use wherever Cabinets are installed for male use.

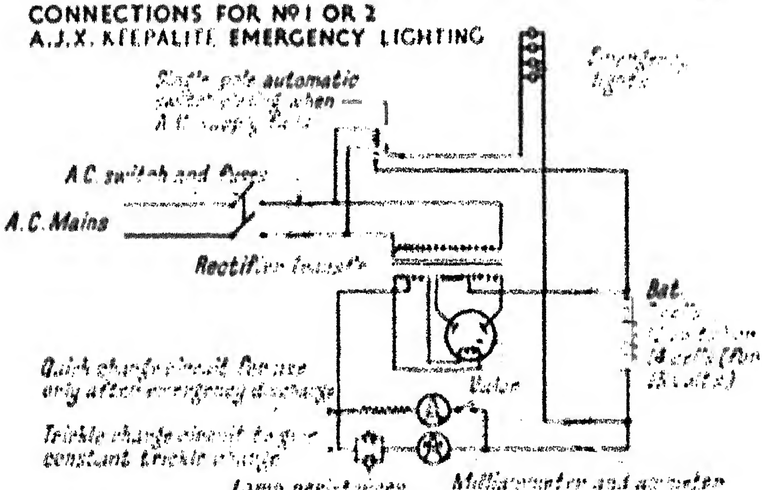
The Austral Auto-flush A.R.P. Cabinet costs £6 6*s*., and the price of the eliminant is £3 7*s*. 6*d*. per case of six 18-lb. tins, each tin consisting of two charges for the A.R.P. model. The estimated cost per head of population for handling and disposing of excreta by this method after emergency can be put at 4*s*.

LIGHTING OF AIR RAID SHELTERS

During an air raid it is not possible to rely upon the maintenance of the ordinary electric service to the mains, and



CONNECTIONS FOR Nº 1 OR 2
A.J.X. KEEPALITE EMERGENCY LIGHTING



PRINCIPAL AND EXTERNAL CONNECTIONS TO CHARGER

FIG. 13 Diagram of Emergency Lighting for Air Raid Shelter.

automatic arrangements for switching in emergency lights should preferably be made.

A hurried search in the darkness for candles or flashlamps would thus be avoided, and as any naked flame consumes the oxygen so valuable to the maintenance of life in the enclosed space, they should be studiously avoided.

The fire risk is also minimised by the use of electric light.

A suitable system consists of a small battery of sealed-in cells, which are kept in good condition by a small trickle charge from the mains and are controlled by automatic switches which require no attention. This method of operation results in a reduction of the wear and tear on the battery and enormously increases its life. The battery is always in a full-charged state ready for an emergency. No skilled attention is necessary. The equipment occupies little space and no special building is required to house it.

To prevent unnecessary use of emergency lighting during supply failures not due to air raids, it is possible to provide a suitable interlock with the entrance to the shelter.

The storage battery evolves no gas or fumes whilst supplying the emergency lighting, nor does it consume any of the valuable oxygen in the shelter.

The Chloride Electrical Storage Co. Ltd. supply equipment of suitable sizes as below :—

TABLE LVI

Equipment No.	1 AJX.	1 DJX.	2 AJX.	2 DJX.
Mains suitable for . .	A.C.	D.C.	A.C.	D.C.
Size of battery . . .	7 ASG 3	7 ASG 3	14 ASG 3	14 ASG 3
Voltage of emergency circuit.	12	12	25	25
Ampere hour capacity of battery in 1 hour . .	15	15	15	15
10 hours . .	30	30	30	30
Total load in Watts the battery can supply for 1 hour	180	180	375	375
3 hours	86	86	179	179
Approximate prices installed	£29 10 9	£27 11 9	£38 13 9	£36 5 9

A typical diagram of connections is shown in Fig. 48.

To provide for the possible failure of the public supply of electricity an alternative auxiliary system of lighting should be installed, the power for which can be generated by similar means to that described for the ventilating plant.

Another suitable type is described below.

Transportable "NIFE-NEVERFAYLE" Emergency Lighting Equipment

One of the great advantages of this equipment is the fact that it has controls for both peace time conditions and for conditions under a national emergency. Further, it is transportable and can be erected in a few minutes, no external permanent wiring being required. Apart from "Off" and "Charging" positions, the master switch can be set for peacetime conditions, where the emergency lights are normally "Off," but automatically connected to battery on failure of the mains, or for air raid conditions where the emergency lights can be operated from main supply to give reduced illumination, and such that they are automatically transferred to the battery when the supply is cut off. The unit is self-contained, the "Nife" battery being housed inside the equipment.

This equipment is made in five sizes, ranging in output from 24 watts to 96 watts, further data being given in the table below.

Hand lights with self-contained accumulator batteries are of considerable use in emergency, and the "Nife"-steel plate batteries, which are able to stand indefinitely and retain a complete charge for years, are especially suitable.

TABLE LVIa

[illegible]	[illegible] Voltage	[illegible]	Maximum [illegible] Watts	Dimensions. [illegible]	[illegible]	[illegible]	[illegible]	Price of Equipment, complete with Battery. £ s. d.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	19 17 6
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	24 10 0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	25 10 0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	38 10 0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	40 5 0

Type FB/25.—Weight 21 lb., and providing twelve hours' light with 9 watt bulb, costs 110*s.*

Type LP1.—Weight 2½ lb., and providing four hours' light with 8 watt bulb, costs 93*s.* 6*d.*

Type U.—Weight 4 lb. 11 oz., providing twenty hours' light with 0 5 amp. bulb, costs 32*s.*

Portable Generators

The Tarpen Portable Petrol-electric Generator may be of considerable use in communal shelters as the generator may be wheeled outside the shelter, connected to the lighting system and left running unattended.

400 watt Model

Engine. Two stroke, air cooled, detachable head, enclosed flywheel magneto, simple carburettor, sensitive electrically operated governor, " Petroil " lubrication.

Generator. Designed and built with armature dynamically balanced and waterproof construction.

Chassis. Sturdy and solid in construction, forms the exhaust silencing system, mounted on two rubber-tyred wheels.

Price. Standard 400 watt 110 volt D.C. unit with power take-off socket, plug and switch. £35.

1 kw. Model

Engine. Four cycle, totally enclosed. Water cooled, fan and radiator, sensitive centrifugal governor, actuating the carburettor and controlling the fuel supply, thereby ensuring maximum economy with a varying load. Slow engine speed. Magneto ignition.

Generator. Designed and built for continuous service. Guaranteed. Fitted three-point enclosed type power take-off.

Coupling. Designed for silent, efficient operation.

Chassis. All steel, including handle, sturdy construction, mounted on rubber-tyred wheels for easy transport.

Price. Complete power unit 1 kW. standard voltage, 220 or 110 volt D.C., with power take-off socket (three-point enclosed type). £60.

CHAPTER V

INDIVIDUAL PROTECTION

THE problem of individual protection involves the provision of a protective device to remove the noxious substances from the air before they are breathed or before they come into contact with the body.

A gas mask cannot be worn continuously, and the individual cannot take sustenance by way of food or drink or obtain much sleep while wearing a gas mask.

Group or collective protection affords a means of protecting the individual during important duties, rest, etc.

Respirators

When the Germans launched their first gas attack in France during the World War they caught the British and French totally unprepared, and with chlorine caused 15,000 casualties, of which one-third were fatalities.

Within the short space of two weeks, in response to an appeal by Lord Kitchener, and thanks to the devoted efforts of British women, all men in the B.E.F. were provided with some sort of protection against gas.

Thereafter followed a race between chemical attack agents and methods and effective defence measures, and at the end of the war the British had sent over no less than twenty-five masks per man to keep pace with wastage and obsolescence.

The study of the development of the gas mask is fascinating and instructive.

From a plaster mould of the remains of a Gladiator victim of the disaster at Pompeii, A.D. 79, and reproduced in the museum there in the position in which it was found in 1755.

A hastily improvised gas muffler very much like the early British masks used at Ypres in 1915.

FIG. 49.

FIG. 50.

By May 3rd, 1915, British troops were issued with cotton cloth pads soaked in a solution of sodium carbonate, sodium thiosulphate and water. Each soldier also had a handful of cotton waste to stuff in his mouth and nostrils. The pads required frequent wetting and gave only temporary protection.

Fig. 51.

By May 10th, 1915, British troops were issued with a black veil respirator which consisted of four folds 8 in. wide and about 1 yard long. The centre portion was padded with cotton-wool and soaked in sodium carbonate and glycerine to keep the pad moist. It was merely tied over the nose and mouth and gave only partial protection.

On the introduction of tear gas the British P.H. helmet was issued. This took the form of a flannelette sack which was impregnated with hypo (sodium thiosulphate), washing soda and glycerine. The lower end of the mask was buttoned under the tunic.

Fig. 52.

On December 11th, 1915, the Germans first used the deadly phosgene gas. The British Intelligence Service obtained five months' notice, and also ascertained the sector in which this would be employed. The attack was successfully met by the timely issue of a modified form of P.H. helmet which had two eye-pieces and an outlet valve of rubber. It was impregnated with caustic soda, phenol and glycerine, producing sodium phenolate, which neutralised the phosgene. It was known as the P. helmet.

FIG. 53.

FIG. 54.

To meet the increasing concentrations of gas in 1916 the British box respirator was introduced. This had a canister filter carried in the haversack connected with a rubber pipe to a mouthpiece. A nose-clip prevented breathing through the nose and close-fitting goggles inside the face-piece were used to protect the eyes against lacrimators.

With but small improvement this mask served the British till the end of the Great War.

FIG. 55.

The type of gas mask employed for horses during the war. The bag was made of layers of cheese-cloth treated with [illegible], which neutralised the gas when the air was breathed through it. It covered the nostrils only, as the horse or mule never breathes through its mouth. The eyes are not seriously affected by lacrimators (see Chapter XIII.).

The modern British civilian mask of the general type, of which over 30 million are manufactured and issued free to the public.

They are in four sizes, suitable for children of from two years to large-size adults. There is no outlet valve, the exhaled air escaping round the edge of the facepiece.

FIG. 56

Civilian duty type of respirator—for use by those whose duties may require them to enter and to work in gas concentrations, and to enable them to carry out those duties efficiently.

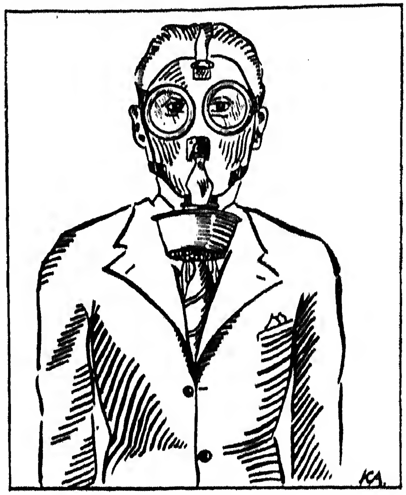


FIG. 57.

FIG. 58.

Civilian duty type of respirator, Mark II, of the official type having standardised filter.

FIG. 59.

British gas bag for small babies. An occasional pressure of the arm works a foolproof pump and maintains the supply of filtered air. See also Fig. 61.

In Czechoslovakia a firm manufactures an "anti-gas perambulator," into which air is pumped through a filter by hand or by the movement of the pram.

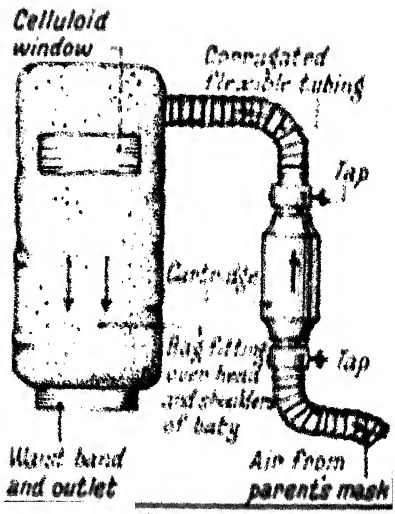


FIG. 60.

A Russian invention provides for a gas-proof bag, into which air from the parent's gas mask is exhaled through a detachable purifying cartridge containing soda lime and activated charcoal. The cartridge lasts an hour and can then be changed even in a gas concentration.

The cost is about 15s.[77]

Fig. 61.—Anti-gas hood for babies.

[To face page 180

Fig. [illegible].—Adjusting Civilian Duty Respirator Mark II. The respirator is of the official type.

ANTI-GAS HOOD FOR BABIES

Fig. 61 shows the Siebe-Gorman anti-gas hood for babies and young children who cannot use a respirator.

It comprises a hood of rubberised fabric, enclosing the upper part of the body, and secured by straps around the waist.

A large oval window of strong cellulose acetate permits the child to see and to be seen, and as the child's arms are free, it can play with toy or doll when the hood is on.

Air is pumped into the hood by means of a rubber bellows through a gas filter which is efficient against all known war gases and smokes.

In use the bellows should be worked to their full extent forty strokes up and down per minute.

The price complete is £3.

THE CIVILIAN DUTY RESPIRATOR (MARK II)

(See Fig. 62)

The Siebe-Gorman civilian duty respirator has been designed to comply with the official specification of the Air Raid Precautions Department governing respirators intended for the protection of persons whose duties may require them to enter and remain in gas concentrations, and to enable them to carry out those duties efficiently.

The respirator has passed all the Home Office tests and bears the Home Office Certification Mark.

In their own interests, purchasers of respirators should look for the Home Office Certification Mark. This mark may be applied only to certified respirators.

DESCRIPTION

Face-piece

The face-piece is a seamless moulding of high-grade rubber, compounded and vulcanised. It is fitted with clear glass eye-pieces, held in position by aluminium frames. Fogging of the eye-pieces by the exhaled breath is prevented by discs of specially treated celluloid, which are placed upon the glasses inside the mask and held in place by steel springs.

The mask is fitted with an exhaling valve, which is bound to a valve-holder of aluminium alloy, the latter being secured to the face-piece by a back plate and four nuts and bolts.

Adjustment of the mask to faces of different sizes is effected by means of a headgear consisting of six elastic straps, which are threaded through slides on the face-piece. Each of the six straps is adjustable, so that the face-piece provides a perfect fit on widely differing faces.

A screwed metal connecting piece on the mask is fitted with a non-return inhaling valve. Into this connecting piece is screwed—

The Filter

The filter is charged with materials for filtering poisonous gases and smokes. It will afford protection for several hours against the types and concentrations of gases which are likely to be encountered in time of war.

Important

It should be noted, however, that the filter affords no protection against carbon monoxide, ammonia, prussic acid gas, and many of the gases and vapours which are encountered in chemical and industrial plants. These are not war gases, and it is unnecessary, therefore, to provide protection against them. Furthermore, the civilian duty respirator, in common with all box respirators, affords no protection against atmospheres deficient in oxygen. Such atmospheres are likely to be encountered as a result of fires in confined spaces. They are frequently encountered, also, in old disused wells.

INSTRUCTIONS FOR USE

1. See that the anti-fogging discs are in place on the inner side of the glasses, and that the eye-piece frames are tightly screwed down. Make sure that the rubber washers are in position in the outer rims. The order of assembly of the eye-piece is (1) washer; (2) anti-fogging disc; (3) glass; (4) inner rim. The treated surface of the discs is marked "IN," and this side should be towards the eyes. The discs must be handled with care, so as to avoid finger marks, which

FIG. 63.—Civilian Duty Respirator Mark II adjusted ready for use.

[*To face page* 182.

FIG. 64.—Testing Civilian Duty Respirator Mark II for gas tightness

FIG. 65. The Siebe-Gorman Civilian Duty Respirator Mark II, with Telephone Transmitter and Receiver.

FIG. 66.—A complete suit of Gas Protective Clothing and Service Respirator. For fire fighting special asbestos suits and carbon monoxide protective masks are necessary.

will impair vision. The discs must be removed before the mask is washed or decontaminated. The glasses themselves should be cleaned before the discs are inserted. (In the absence of the anti-fogging discs, or if these become scratched or damaged, treat the eye-pieces with the anti-dimming compound provided in accordance with the instructions on the tube.)

2. To put the mask on, hold it by the side elastic bands, with the thumbs under the two lower bands on either side (see Fig. 62). Put the chin into lower part of the mask, and pull the headbands over the head. The rubber and canvas pad, through which the headbands are threaded, should be in the centre of the back of the head (see Fig. 63). Adjust the headbands in turn, so that the face-piece is drawn into firm but comfortable contact with the face, and so that all the bands exert an equal pull. Test the mask for gastightness by blocking up the bottom of the filter. A book having a smooth, stiff cover is suitable for this purpose (see Fig. 64). The adjustment of the headbands should be such as to ensure that the mask is firmly and comfortably secured to the head. It should not slip if the wearer moves his head vigorously, or if he bends down and nods his head. Note that excessive tightness of the headbands may cause leaks by distorting the face-piece.

Storage

See that the mask is not folded or crushed when not in use. It is preferable to remove it from its haversack and keep it in an airtight tin in a cool dry place.

Testing Respirators

The efficiency of the civilian respirator shown in Fig. 56 depends upon how well the face-piece fits the head, the skill of the wearer in putting it on, and on the size and contents of the filtering canister.

A section of the canister is shown in Fig. 67.

The activated charcoal absorbs the true gases and the pad of wool and asbestos fibres the smokes.

In the service type of respirator designed for use in higher concentrations of gas the canister is larger and the smoke pad thicker.

In some masks it is replaced by pleated paper for greater protection against the more penetrating smokes.

Activated charcoal in the form of small granules is the most suitable substance for the chemical filling of gas mask canisters.

During the war it was made from cocoanut shell fruit stones and other dense raw carbons.

It is now made from a variety of materials and consists of a very porous charcoal made by the carbonisation of organic matter. Subsequent heat treatment with steam by a process called "activation," increases the property of *adsorption* of gases by which the charcoal attracts and physically holds the molecules of gas like iron filings upon a magnet.

Activated charcoal, as commercially available, usually adsorbs about half its own weight of toxic gas but highly activated carbons can be specially prepared to adsorb their own weight of gas.

When soda lime is added chemical absorption is introduced thus cleaning impregnated granules and rendering them again effective.

Soda lime is a mixture consisting of hydrated lime, cement, sodium hydroxide kieselguhr and water in various proportions, and as the temperature increases its activity rises, thus counteracting a fall in the adsorptive properties in the charcoal accompanying a rise in temperature.

The general civilian respirator is issued with the general assurance that it is "perfectly effective against all war gases," and on test has shown that it will be effective against chlorine for one hour against a concentration of 1 in 200.

The solid particles in cigarette smoke are approximately the same size as those in the arsenical smokes, and a useful indication of the efficacy of a filter can therefore be obtained by attempting to blow cigarette smoke through the canister.

This can be done by temporarily removing the inlet valve and after inhaling smoke to exhale it through the filter with the mask firmly adjusted.

The general civilian respirator is not entirely effective in the filtration of fine smokes, and should therefore not be relied upon for work in high concentrations.

After adjustment of the face-piece the general gastightness of the respirator can be tested by covering the inlet to the

canister and inhaling strongly. If the suction is not sufficient to draw the rubber of the face-piece close to the face, then it is not sufficiently gastight and adjustments are necessary.

Normally ordinary glasses cannot be worn unless that part of the frame which normally rests on the ears is replaced with a close-fitting tape or eye-glasses of the pince-nez type are used.

It should be noted that the anti-dimming compound provided with the respirator must be used on both sides of the glass of the spectacles.

The recommendations for the testing, adjustment and preservation of the service and civilian duty respirators are given in A.R.P. Handbook, No. 1, to which the reader is referred for detailed information.

Care of General Civilian Respirators

1. Respirators must be protected from wet, and when not in use should be kept, if possible, in a cool, dry, dark place.

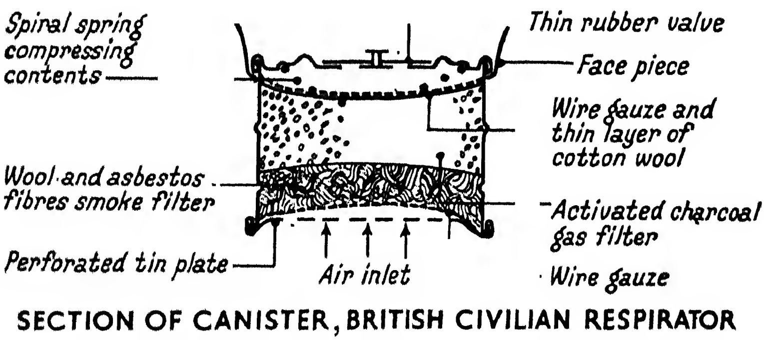


Fig. 67. Section of Canister used on the general Civilian Respirators.

2. Prolonged storage of the respirator in a folded position in haversack or container is likely to cause leaks in the face-piece, and this can be avoided by occasionally wearing the respirator.

3. After use the head harness and the inside of the face-piece should be wiped dry and any rain removed from the exterior before the mask is put away.

4. The inside of the face-piece can be maintained in a whole-

some condition when in use by periodic sponging of the whole of the interior with a weak solution of one part of Izal in 200 parts of water, and subsequently sponging with clean water and drying.

5. Respirators should only be used by the persons to whom they have been issued and fitted, and should be disinfected each time it may be necessary for them to change hands. In any event they should be disinfected once every six months.

Protective Clothing

Persistent gases like mustard gas will attack the hands and face not covered with a gas mask, and, although ordinary clothing is of some value, it is dangerous to trust to protection by it for any length of time ; indeed, absorbent clothing may retain a persistent liquid gas and cause blisters many days after infection.

For those whose duties necessitate their working in proximity to concentrations of persistent gas, protective clothing of a non-porous oilskin is necessary.

A complete suit consists of oilskin hood, oilskin jacket, oilskin trousers, oilskin gloves and rubber gum-boots (to the knee).

Only underclothing should be worn under this suit. The rubber boots are necessary because leather gives only a short period of protection against mustard gas and is difficult to decontaminate.

A photograph of a man equipped with a complete suit of protective clothing is reproduced in Fig. 66, and as the clothing is non-porous the heat and perspiration from the body are retained inside, thus causing rapid fatigue.

Where adequate ventilation can be arranged to avoid dangerous concentrations of vapour, so that the only danger is from touching contaminated objects, the modified suit with coat or apron with sleeves, gloves and gum-boots may be used. Brief particulars of the cost of protective clothing against gas are given below.

BRIEF PARTICULARS OF RESPIRATORS, GAS-PROTECTIVE CLOTHING AND FIRE-FIGHTING EQUIPMENT

1. *General Civilian Respirator*, Fig. 56. This respirator comprises a face-piece of sheet rubber, non-inflammable

cellulose acetate window and adjustable head harness. It is fitted with the same container as that supplied with *Civilian Duty Respirator, Mark II* (see Figs. 62 and 63). No general civilian respirator is yet certified by the Home Office, since certification procedure in respect of this type has not yet been evolved. The price of this respirator, complete with cardboard box and available in three sizes, is 5*s*. each. Spare containers 3*s*. each.

2. *Siebe-Gorman Civilian Duty Respirator, Mark II.* As will be seen from the illustrations (Figs. 62–63), this respirator is similar in appearance to that described in Air Raid Precautions Handbook, No. 1. It differs, however, in the following respects :—

(*a*) The eye-piece frames are of stainless steel instead of tinned iron.

(*b*) It is fitted with renewable discs of specially treated non-dimming cellulose acetate, which are inserted on the inner sides of the eye-pieces to prevent the misting normally caused by the exhaled air.

(*c*) The eye-pieces are of unshatterable glass.

The price, complete in haversack, is 16*s*. 6*d*.

3. *"Puretha" General Service Respirator.* The "Puretha" respirator is illustrated in Fig. 66. It is carried in a canvas haversack. The face-piece is similar to that used by the Army and Navy, whilst the container is of special design. The latter is of high efficiency, and its performance complies with the War Office requirements for containers of the general service type. The price of the complete respirator is £1 15*s*.

TABLE LVII

Gas-Protective Clothing

Recommended outfit for decontamination and demolition squads :—

Heavy Pattern :

Jacket	17/5 each.
Trousers	12/5 per pair.
Gloves	4/3 ,,
Hood	3/8 each.
Rubber gumboots . .	10/6 per pair.
Steel helmet . . .	12/6 each.

Recommended outfit for first-aid parties, messengers, etc. :—

Light Pattern :

Jacket	11/3 each.
Trousers	5/11 per pair.
Gloves	4/3 ,,
Hood	3/8 each.
Rubber gumboots . .	10/6 per pair.
Steel helmet . . .	12/6 each.

Recommended outfit for cleansing station undressers :—

Light Pattern :

Sleeved apron . . .	7/2 each.
Gloves	4/3 per pair.
Rubber gumboots . .	10/6 ,,

Fire-Fighting Equipment

Fire-fighting equipment designed in accordance with Home Office specifications :—

(*a*) Sand container, scoop and hoe, for smothering and removing light incendiary bombs . . .	17/6 per set.
(*b*) Stirrup fire pump, complete with 30 ft. of hose and stand . .	22/6

First-aid pouches and surgical haversacks, as described in Air Raid Precautions Memorandum No. 1 :—

1. First-aid pouches . . .	10/6 each.
2. Surgical haversacks . . .	25/- ,,
3. Householder's first-aid kit . .	5/- ,,

Table LVIII

A Selection of Bell's Asbestos Protective and Fire-fighting Equipment

Ref. No.	Description.	Uses.	Price.
A.R.P. 1 (F. 53)	**Bestobel Special Equipment** As supplied to the Royal Air Force. Made in two pieces, and thus the wearer is able to keep the lower half on when on duty, putting on the upper part only in emergencies. An Air Vent, with a spring loaded hinge flap, is fitted in the peak of the Helmet, which can be closed before the wearer enters the flames to effect a rescue. Suit complete, excepting Gloves.	Designed for very rapid adjustment and maximum amount of mobility to the wearer. Can be used in fierce flame conditions.	£36
A.R.P. 2	**Combined Light-weight Equipment** This Asbestos Suit allows great freedom of movement and affords ample protection to a man passing through, or remaining close to, serious fire conditions.	Can be put on over ordinary clothes and boots. This equipment is particularly suitable for Fire Brigades.	£13
	Helmet, Suit, Boots, all in one.	(In coarser and heavier cloth.)	£8 10 0
A.R.P. 131 (F. 18)	**Special Gauntlets** Recommended for use with this equipment.		39/- per pair
A.R.P. 33	**Asbestos A.R.P. Blankets** A light Asbestos Blanket with quick-release Satchel, rendering it easily portable. Available in the following sizes :— 5′ × 3′ 4″ with Satchel.	Provide a rapid smothering agent at the inception of any type of fire. These Blankets, by the protection they afford the operator, enhance the value of chemical fire extinguishers. Under certain conditions they may prove more effective than any chemical fire extinguisher. They have the additional advantage that they do not require to be recharged. The Blankets can be used repeatedly.	17/6 each

Ref. No.	Description.	Uses.	Price.
A.R.P. 5	**Asbestos Fire Blankets** Size 6′ × 5′ Non-fluff Blanket complete in triangular container.	As A.R.P. 33. They form effective temporary fire bulkheads.	33/
A.R.P. 6	Size 3′ × 3′ Non-fluff Blanket, complete in circular container.		
A.R.P. 7 (F. 70)	**Asbestos Folding Shield** With special clamp to take Branch pipe. Approx. dimensions:— Closed, 16″ × 48″ Opened with apron dropped, 50″ × 76″ Approx. weight, 15 lb.	Of great value in allowing operator to approach close to an incendiary bomb, or to the seat of a fire when using sand, chemical extinguisher, or hose. The mica window provides ample vision. These shields will be particularly useful when dealing with incendiary bombs. They also form effective temporary fire bulkheads.	
A.R.P. 8 (F. 71)	**Asbestos Light Fire Shield** With Apron extension. Approx. dimensions: With Apron folded, 41″ × 32″ With Apron dropped, 75″ × 32″	A lighter pattern shield than A.R.P. 7	54/-
A.R.P. 31	**Asbestos Face Protector** Peaked cap with asbestos skirt hanging from peak and reaching shoulders, fitted with ruby glass eyepieces.	Protection against excessive heat.	10/6 each
F. 16.	**Special Asbestos Gauntlets** Leather lined. These Gauntlets are made with a completely seamless padding, and whilst retaining flexibility, provide a very high degree of protection.	Suitable for fire fighting. This Gauntlet is supplied with the Air Force Equipment, Ref. A.R.P. 1.	73/- per pair
A.R.P. 14	**Asbestos Gauntlets** Made from Asbestos cloth, fingerless, with Double Palms, Calico lined. 21″ long.	For handling any hot material.	10/- per pair
A.R.P. 17	**Asbestos Gauntlets** Made from Asbestos cloth, fingerless, single palms, calico lined. With elastic wrist band.	For handling any hot material.	4/6 per pair

Ref. No.	Description.	Uses.	Price.
M. 21	**Asbestos Paper** In Rolls 40″ wide. 1 cwt. Rolls or less. Thickness / Weight per sq. yd. 0·007″ — 3·75 oz. 0·010″ — 5·16 oz. 0·020″ — 11·25 oz.	When attic or loft floor is covered with earth or sand, Asbestos Paper forms a cheap and efficient fire proofing, for rafters, etc., against incendiary bombs. Can be easily fixed to woodwork with drawing-pins. Experience shows that the "splash" from an incendiary bomb will not ignite rafters protected in this manner.	1/6 per lb.
A.R.P. 20	**Asbestos Cloth Curtains** Not waterproofed.	For Air Raid Shelter entrances. This material is FIREPROOF, ROTPROOF and RAT-PROOF.	From 5/6 per sq. yd.
A.R.P. 21	**Asbestos Cloth Curtains** Non-fluff. Plain Colours.	Provide an efficient and cheap method of preventing fire from spreading along alleyways and corridors, long enough to allow people to make good their escape without being hampered by heat and smoke. Will withstand temperatures averaging 1,200° F. for as long as six hours.	From 9/6 per sq. yd.
S. 3	**Asbestos Fireproof Millboard** Special Quality A specially hard board with a smooth surface. Can be supplied in sheets up to 12′ × 4′ 6″, 1/32″ to ½″ thick.	A fire-resisting panelling material. May be used in conjunction with Bestobell Felt.	1/- per lb.

Bestobell Bomb Snuffer

A wire mesh frame specially strengthened and sprayed inside and out with asbestos fibre finished with a hard surface. Provided with a 2-in. diameter ring at top to facilitate handling. Will effectually prevent any spread of fire from an incendiary bomb which has fallen on a non-inflammable surface. A handle not less than 6 ft. long with hook at end should be used to place in position. (See Fig. 20).

Price:
Snuffer 16/9
Plain wooden handle fitted with hook at end
1/3 each.

Portable Fire Shield

A light yet rigid flame shield of 3DF2 DURASTEEL panelling has been developed for the use of factory fire parties or A.R.P. squads. It is $\frac{1}{8}$ in. thick, with channel steel bound edges, and weighs approximately 22 lb. Size 4 ft. by 2 ft. Note narrow observation slit and webbing arm straps. Operator can approach a thermite incendiary bomb with safety if equipped with the DURASTEEL 3DF2 fire shield. Price 35s. each. (See Fig. 21).

CHAPTER VI

BUILDINGS

Generally

To design a structure giving protection to the occupants against aerial attack the architect and structural engineer must consider the forces of direct impact, the penetration of splinters, blast from explosion, earth vibrations, falling building material, fire and the penetration of gas, noxious chemicals and bacteria.

Materials

Apart from the use of steel armour plate, reinforced concrete has been found to be the best medium of building construction for the greater degree of all-round protection.

Experiments carried out by the French authorities indicate that the penetration of heavy bombs into reinforced concrete, mass concrete, brickwork and normal earth is approximately in the ratio 1 : 1·5 : 3 : 10 respectively.

Planning

The general question of town planning for minimisation of the effect of aerial bombardment is discussed in Chap. XIII. but large buildings, such as modern blocks of flats, can be made less vulnerable to the effects of aerial attack by careful planning.

Courtyards closed on all sides should, where possible, be avoided and light well areas also avoided by cruciform planning with all windows facing outwards from the block.

Where congestion of population is inevitable, it is preferable to plan buildings to be of the greatest permissible height in order to minimise the ground floor area and to keep the target as seen from the air as small as possible, with large and unconfined spaces between the buildings.

It is true that the bomb approaches at about 75 degrees to the horizontal, and therefore the chances of hitting a tall building are increased, but the provision of uncongested open

spaces is of considerable importance. Such open spaces minimise the effects of blast from explosions and permit of freer circulation of air and the consequent increased dissipation of the products of the explosion or noxious gas.

Official recommendations regarding the provision of shelter protection include, *inter alia*, the following.

The main principles which should be kept in mind in considering the selection and suitability of shelter accommodation in general are :—

1. *Overhead and Lateral Cover.* The effectiveness of shelter accommodation, whether in buildings or independent of them, is primarily determined by the nature of the overhead cover and lateral protection. The more substantial the protection afforded by the roofs, walls and floors of a building in which shelter accommodation is situated the greater degree of protection.

2. *Location of Building containing Shelter Accommodation.* The most suitable sites are those in wide streets or squares or facing open spaces.

Unsuitable sites are as follows :—

(*a*) Near areas of possible military importance.

(*b*) Adjoining buildings having a low standard of fire resistance.

(*c*) In the neighbourhood of buildings in which the occupancy involves abnormal fire risks, such as the manufacture or storage of celluloid, paints or other highly inflammable material.

3. *Character of Building containing Shelter Accommodation.* As a general rule, multi-storey steel-framed or reinforced concrete buildings are the most suitable type for containing shelter accommodation. They should, however, be of fire-resisting construction, preferably with solid concrete floors and roofs and solid cross walls or partitions, and have a fair proportion of solids to voids in the external walls. The lift shafts and staircases should be totally enclosed.

The following features in the design, construction or occupancy of multi-storey buildings are disadvantageous in connection with the provision of internal shelter accommodation :—

(*a*) Large proportion of voids over solids in external walls.

(*b*) One-cell floors, or floors with no partitions between external walls.
(*c*) Timber floors or roofs or floors of weak construction.
(*d*) Buildings with doubtful lateral strength.
(*e*) Roof lights with horizontal or sloping glazing.
(*f*) Heavy objects, such as tanks, safes and machinery on upper floors.
(*g*) High chimneys and parapets or heavy architectural features, such as heavy cornices and pediments, large gables or towers above roof level.
(*h*) Buildings in which the occupancy involves abnormal fire risks.
(*i*) Enclosed courts or light wells, owing to the increased risk of damage by blast from bombs falling in the enclosed space.

Where such enclosed courts are unavoidable, it is essential that all enclosing walls should be carried down to the level of the lowest floor, and such walls should have the minimum number of openings, which should be capable of being blocked up or otherwise protected in case of emergency.

Single-storey buildings which are also frequently of the one-cell type, *e.g.*, theatres and some schools. Factories which have roofs over large areas are quite unsuitable, and, apart from some form of protection for machinery, factories must be evacuated in event of air attack.

4. *Location of Shelter Accommodation in Building.* In general, it may be said that below ground accommodation is best, as it is likely to have a greater degree of 'ateral protection, but it is highly desirable that such accommodation should not be lower than the water mains or sewers. If this is unavoidable, the accommodation should be constructed as a tank with entrances above flood level.

Where the walls are of sufficient thickness to afford lateral protection and the windows are of normal size, and providing that effective gas-proofing is possible, the ground floor of a building may be considered as suitable for the location of shelter accommodation.

Shelter accommodation on upper floors should generally be not lower than the second floor, and should have a minimum cover of two floors and the roof of the building.

Shelters should not be adjacent to internal courts or light wells, and should not be sited immediately below large water storage tanks, safes or heavy machinery, which might be dislodged by a bomb and crush the roof of the shelter accommodation.

5. *General Construction.* The most satisfactory material for use in constructing rooms which could be adapted for use as shelter accommodation is reinforced concrete, and such rooms will normally be linked to the framework of the building, and be an integral unit of it. Shelter accommodation may be specially built in the basement of a building, in which case it would be possible to construct it independently of the framework of the structure. The floor forming the roof of the shelter accommodation should be constructed of solid reinforced concrete with reinforcement running in both directions so that it is capable of taking concentrated loads, due to falling *débris*, from the floors and roof above in the event of demolition.

Reinforced brickwork provides a satisfactory alternative material for the walls of the shelter accommodation.

It is important that the walls and roof of the shelter accommodation should not be pierced by pipes or conduits. Where this is unavoidable, the holes should be efficiently caulked with some elastic material such as bitumen, and facilities for shutting off all gas and water services by means of suitable stop-valves should be provided.

In order to obviate the risk of falls, owing to vibration or shock, the ceilings should not be plastered, but should be finished with fibre board. This will help conditions in an air-locked chamber by absorbing moisture and also act to some extent as a sound absorbent. The fibre board should be laid on the forms before the concrete is deposited.

In multi-storey buildings the stair well, lift shaft and such circulating spaces are, as a rule, the most fire-resistant and most structurally sound portions of the building. They can at slight extra cost be provided with a special reinforced concrete light bomb-proof or bomb-deflecting roof generally, as shown in Fig. 13.

Two alternative roofs are indicated, and the designer must select that which is most suitable to the case under consideration.

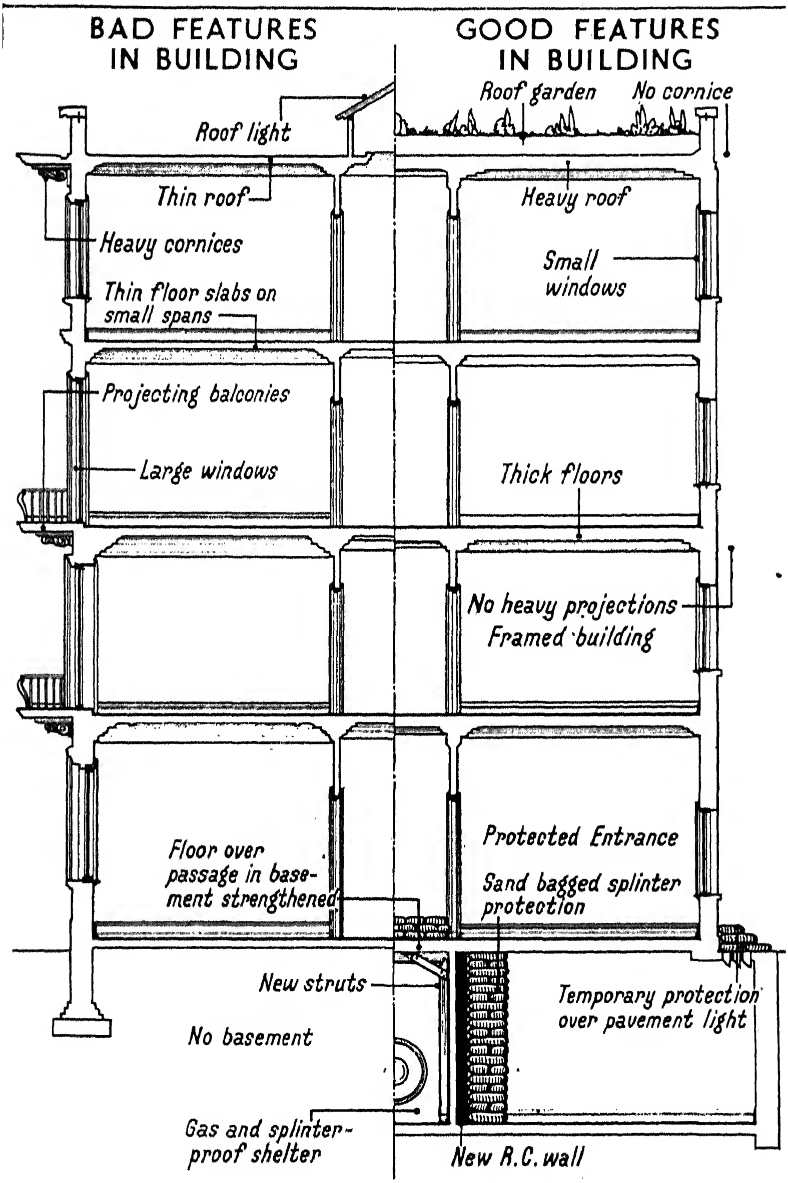


FIG. 68.—Desirable and undesirable features in building—considered from the point of view of the disruptive effects of aerial bombs. The good features do not involve additional cost.

Such a construction involves only the thickening of the concrete roof of the building and the strengthening of the columns to carry the additional load. The staircase should be so placed that it can be quickly reached in the case of alarm and be sufficiently protected to provide a safe communication for the occupants of the building to a shelter at the base of it.

Apart from going deep underground, what type of building is best constituted to resist the effects of the aerial bomb ?

It is difficult to generalise on the matter, but Fig. 68 shows on the one side some desirable features in buildings, and on the other some features which should preferably be avoided. Heavy cornices, projecting balconies and stone ornament projecting considerably over the pathway below are a potential source of danger to pedestrians and may block areas and shelter exits during an air raid.

Thin roof and floor slabs economically associated with small spans in framed buildings are not so resistant to the penetration of bombs and splinters as are thicker slabs associated, if necessary, with larger spans.

In the same way solid reinforced concrete slabs with two-way reinforcement are preferable to the hollow-tile types from this point of view.

The provision of large windows is a feature of modern building, but for the provision of protection from blast and splinters small windows are preferable.

The whole of the good features depicted in Fig. 68 can be adopted in multi-storey building when in the design stage without any ultimate addition to the cost.

It will be noted that the position selected for the gas-proof and splinter-proof shelter depicted in Fig. 68 is under the corridor—below ground level and remote from the side walls of the building. In this way the shelter roof span to be strengthened is small, and the penetration resistance of the upper floors is utilised as additional protection.

An official Swiss publication [79] states that the thickness of protecting roofs over shelters can be reduced as in the following table in cases where there exist other slabs over the shelter. The upper floor or roof slabs, which would not be penetrated by a bomb approaching any part of the shelter roof, with an

angle of incidence of 15 degrees to the vertical, must not be counted when using the following table (see also Fig. 70).

Table LIX
Reduction of the Thickness of the Top of the Shelter by the Effect of Other Floors Above

Upper Floors.	Wooden or Iron joists with filling.	Reinforced Concrete slabs with normal reinforcement.			
		5	10	12	15
Reduction of the thickness of the top of the shelter in special reinforced concrete, 5,690 lb. grade	Uncertain	1″	1½″	2″	2½″
Reinforced concrete, 3,130 lb. grade	Uncertain	1¼″	3¼″	4″	5″

Aerial bombs are resisted completely in the following thicknesses of slabs :—

Table LX
Thickness in Reinforced Concrete of Detonating Slabs (Total Arrest of Bomb)

Weight of Bombs.	Special reinforced Concrete following. 5,690 lb. grade.	Reinforced Concrete. 3,130 lb. grade.
50 kg.	1′ 8″	2′ 2″
100 ,,	2′ 6″	2′ 10″
300 ,,	3′ 2″	4′ 1″

Detonating slabs in reinforced concrete, inclined at an angle of 45 degrees or more in relation to the horizontal, provide full protection at the following thicknesses :—

Table LXI
Thickness of Shelter Roofs in Reinforced Concrete inclined at 45 degrees

Weight of Bombs.	Necessary thickness for : Special reinforced Concrete (5,690 lb. grade).	Reinforced Concrete (3,130 lb. grade).
50 kg.	1′ 2″	1′ 6″
100 ,,	1′ 8″	2′ 2″
300 ,,	2′ 4″	3′-0″

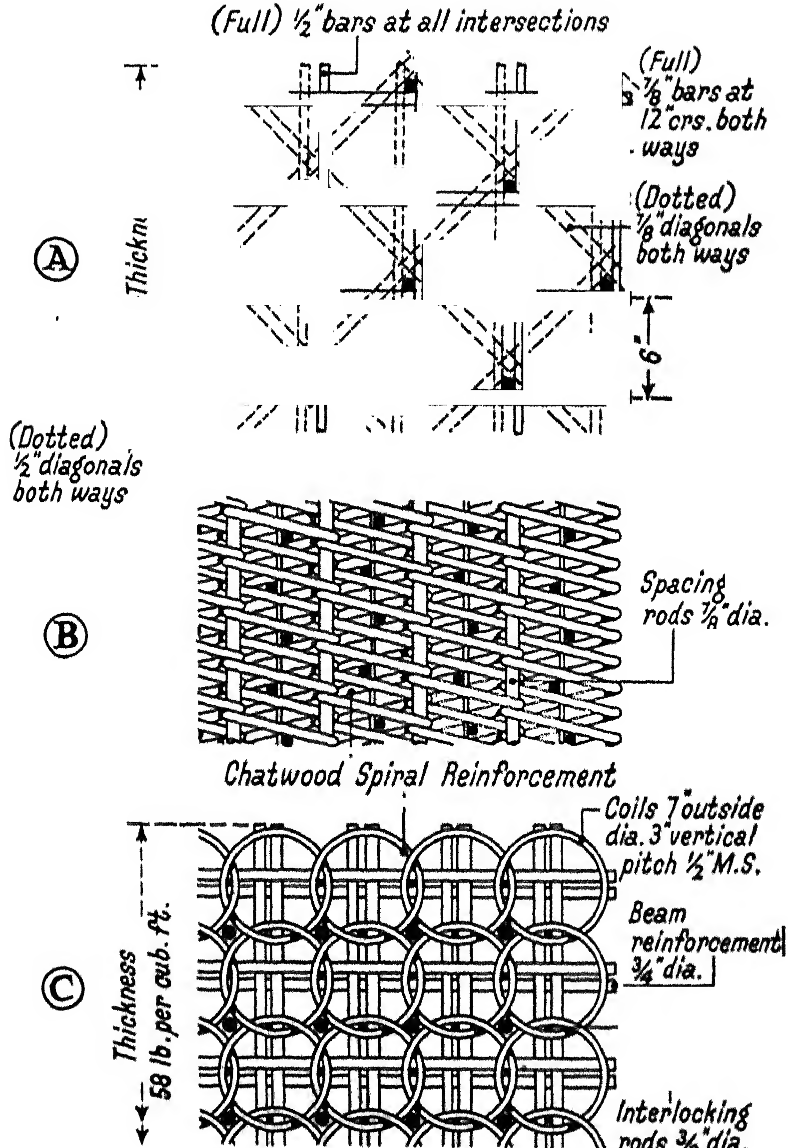


FIG. 69.—Showing alternative arrangements of special reinforcement in concrete shelters.

The superiority of concrete for the construction of air raid shelters is confirmed by the French Ministry of Interior, who make the recommendations shown in Table XII.

The French Ministry of Interior suggest a reduction of roof thickness on account of superimposed floors as follows :—

TABLE LXII

	in.	in.	in.
Thickness of superimposed floor . . .	2	4	6
Reduction of thickness of shelter roof for each superimposed floor :			
Reinforced concrete	1¼	3	4¾
Mass concrete	1¾	4¾	7

The thickness of reinforced concrete required will also depend on the method of reinforcement adopted ; tests are being carried out in this country to determine the relative values of alternative designs. There are reasons to believe that a spiral type of interlinked reinforcement, which is to a certain extent resilient in itself, may prove to be more effective than a more normal type of reinforcement, and may lead to a reduction in the thickness of concrete required.

Special Reinforcement

The special types of reinforcement referred to in the Swiss and French Government recommendations involve the use of rectangular grids of plain steel rods arranged in three planes generally as shown in full lines at A in Fig. 69, and weighing 10 lb. per cu. ft. plus any additional beam reinforcement necessary.

Under attack by armour-piercing ordnance concrete slabs reinforced in such a manner tend to laminate unless four additional grids of reinforcement arranged at 45 degrees to those already shown in full on the figure are introduced. These additional diagonal bars are indicated in dotted lines at A in Fig. 69. It will readily be understood that in order to be able to insert these diagonal grids, producing seven-way reinforcement, weighing 25 lb. per cu. ft., most accurate pitching of all bars must be ensured and a certain amount of welding is therefore involved.

The arrangement gives the highest resistance to penetration

through reinforced concrete yet discovered, but the seven grids, together with additional beam reinforcement, cause such obstruction in the interspaces that considerable difficulties are encountered in placing concrete and ensuring a solid mass without voids.

The Chatwood Safe Co. Ltd. is using a method of reinforcing monolithic concrete slabs, which expresses " reinforcement in all directions " in a practicable form.

The superiority of this system has been demonstrated by scientific and practical research and test, but previously the difficulties of its assembly and setting up ready for concreting have prevented it from being a commercial proposition.

" Mattresses " of the Chatwood Patent Spiral Reinforcement Fabric—well known in the construction of burglar-proof strong rooms—provide a framework for correctly spacing and securing the horizontal, vertical and beam reinforcement.

The " Mattresses " consist of interwoven steel coils, the planes of which run diagonally in four directions, and so perform the function of the diagonal members in " Allway " reinforcement.

This system of reinforcement has the essential features for structural strength, resistance to penetration and to the punching shear effect of bombs as well as resisting the effect of explosion when the reinforced slab is partially penetrated.

This patent spiral reinforcement, arranged generally as shown at B and C in Fig. 69, has given remarkable results on test, even against armour-piercing projectiles having high impact velocities. The arrangement does not prevent the tamping or vibrating of concrete into position, and concrete free of voids and reinforced uniformly in all required directions is ensured.

Ordinary principles of reinforcement are not applicable to this type of mattressed slab which approximates the ideal as a cheaper substitute for armour-piercing steel plate and which can be " cast " in situ to any desired shape.

By suitably arranging the number of rows of coils in the thickness of a " mattress " any required degree of protection can be obtained.

In designing roof slabs for shelters in buildings the weight of *débris* of the whole building collapsing upon the shelter

should be taken into account, together with any goods, merchandise, etc., stored on the upper floors. The effect of "arching of load" to a large extent counteracts the effects of impact due to the suddenly applied load, and the Swiss official recommendations state that the shelter shall be calculated with regard to the whole of the load situated above plus point loads as below.

For buildings of three storeys or more a concentrated load of 20 tons shall be calculated as concentrated within a circle of 10 in. diameter. For buildings of one or two storeys this point load may be reduced to 15 tons. These point loads are intended only for calculations of punching shear.

Table LXIII

Load on the Protective Slabs by the Collapse of the Construction Materials

Number of Storeys.	Load in lb. per sq. ft.	
	Building with reinforced Concrete.	Building with Wooden Beams.
	lb. per sq. ft.	lb. per sq. ft.
Ground floor + 4 storeys + roof . .	1,200	1,000
,, ,, + 3 ,, + ,, . .	950	850
,, ,, + 2 ,, + ,, . .	700	650
,, ,, + 1 storey + ,, . .	450	410

For buildings with floors designed for a normal superload of 100 lb. per sq. ft. it has been suggested that the roof of the shelter should be strong enough to sustain a static load of 80 lb. per sq. ft. for each of the floors above. On this basis, in a building with nine upper floors and a roof, the roof of a basement shelter would be designed for a total emergency load of 800 lb. per sq. ft.

In Germany the roofs of basement shelters have to be designed for a minimum extra load of 200 lb. per sq. ft. for buildings with two complete floors, 300 lb. per sq. ft. if there are three or four floors, and 400 lb. per sq. ft. if there are more than four floors.

The official recommendations [118] in this country include, *inter alia*, the following prescribed demolition loads:—

1. For buildings where loads are carried on load-bearing brickwork or masonry :—

LXIV

Number of Storeys Over.	*Débris* Load to be Assumed per sq. ft. in Addition to Normal Load.
2	200
3 or 4 . . .	300
More than 4 . .	400

2. In steel or reinforced concrete *framed* buildings the *débris* load to be taken as 200 lb. per sq. ft., irrespective of the number of storeys over.

3. Composite buildings partly framed may give intermediate *débris* loads based upon the judgment of competent architects or engineers.

(See also section on Strengthening of Buildings.)

In some London banks the allowance made for the load of *débris* on the underground strong rooms and shelters is as much as 2 tons per sq. ft.

The table below shows slab thicknesses and reinforcement required for free-ended span roofs of shelters loaded to 5 cwt. per sq. ft. in addition to the dead load.

The grid reinforcement provides for localised effects of falling masonry, but very considerable additional strength (especially against penetration) can be obtained by the use of a grid of steel reinforcement in the top of the slab connected with substantial links, not less than ¼ in. diameter at 12 in. c/c. each way, to the grid in the bottom. The diagonal arrangement of the grid overcomes difficulties of proportions of long slabs and develops " square slab " effects to a certain degree irrespective of the plan shape of the shelter.

For strengthening a roof, if columns and bearers can be placed under the existing roof or ceiling to reduce the unsupported span, halving the span roughly allows four times the load safely to be carried. The roof should be jacked up to ensure that the new work takes its due share of the load, and

TABLE LXV

Maximum tension in steel, 18,000 lb. per sq. in.
Maximum compression in concrete, 750 lb. per sq. in.
Modular ratio, 15.
Concrete slabs, free-ended, 1 : 2 : 4 mix.

Span.	Thickness of slab.	Reinforcement M.S. bars.
6′	6″	½″ dia. bars, 6″ c/c. each way diagonally across slab.
7′	7″	
8′	8″	⅝″ ,, ,, ,, ,, ,, ,,
9′	9″	
10′	10″	
11′	11″	
12′	12″	¾″ ,, ,, ,, ,, ,, ,,
13′	13″	
14′	14″	
15′	15″	
16′	16″	⅞″ ,, ,, ,, ,, ,, ,,
17′	17″	
18′	18″	
19′	19″	
20′	20″	
21′	21″	1″ ,, ,, ,, ,, ,, ,,
22′	22″	
23′	23″	
24′	24″	
25′	25″	

the reliability of the column foundations is important. The work should be carried out by competent engineers, particularly if the existing roof is of reinforced concrete and no plans showing the arrangement of the reinforcement are available.

If the floor above can be taken up, and the framing is in timber, the roof of the shelter can be strengthened with concrete between the joists, possibly adding a main girder below to reduce the span of the joists. Alternatively, the old ceiling can be replaced entirely in reinforced concrete designed to give the required strength, in which case concrete columns with splayed reinforced capitals and footings can be incorporated as part of the design. Each case should be considered on its merits and expert advice obtained before the work is undertaken, especially as strengthening work is more difficult to design and execute than is ordinary new construction.

The use of concrete barrel vaulted additional strengthening construction inside an existing basement provides considerable

scope, and should preferably be adopted when the strengthening of the ground floor by the methods indicated above cannot be adopted.

Walls to Basement Shelters

The outside walls of basement shelters should, of course, be capable of taking all the external forces acting upon them, especially the horizontal thrust due to earth pressures or blast, when the stabilising effect of superincumbent loads might have been removed by the collapse of the building.

Earth tremors due to nearby explosions of bombs also have to be allowed for, and to this end if the wall is a long one buttresses at frequent intervals should be constructed and the roof and ground concrete reinforced continuously with the side walls.

The minimum thickness of side walls of basement shelters should be 12 in. with reinforcement on both sides of the wall, and it is a good plan to make the wall at least one and a half times as thick as the roof slab.

For internal walls 12 in. of plain concrete or 6 in. of reinforced concrete would normally provide sufficient isolation, but in the case of large basement shelters divided into a number of cells each with their own exits and entrances, the dividing walls should have the thicknesses specified for full splinter-proof protection given on p. 38, and should be made stronger than the rest of the work.

Floors

In strengthening a basement for the purpose of constructing a shelter, due regard must be paid to the additional load on the foundations. It is desirable that the floor of the basement be of concrete monolithic with the walls and of a thickness of at least $\frac{1}{2}$ in. for each foot of the distance between the walls. The reinforcement should be approximately the same as that given in Table LXV, and should be disposed appropriately to resist the tensile stresses, usually near the top of the slab.

General Remarks

Basement shelters should preferably be constructed above the level of drains, but where this is not possible they must be made water-tight by any of the usual approved methods.

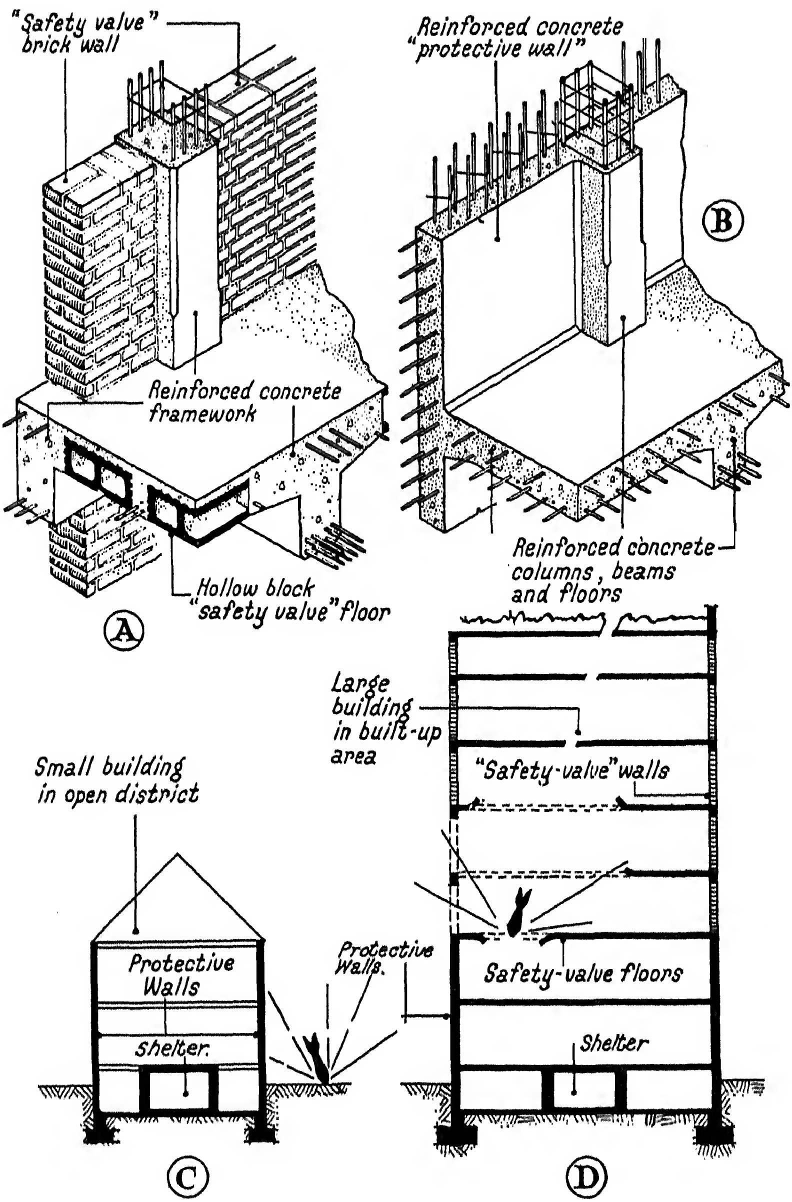


FIG. 70.—Framed buildings showing effect of "safety valve" walls and "protective" walls.

Gas-proofing, ventilation and lighting should, of course, be dealt with as previously explained.

In new buildings much subsequent labour and expense can be saved if shelters in the basement or the ground floor are designed before the building is constructed. Their peace-time use as stores need in no way be interfered with, provided permanent storage fixtures are not installed.

Framed Buildings

As already stated, no building to-day can be made entirely resistant to direct impact, and on the whole in a built-up city area a framed building is preferable to one of the traditional type, in which floors are carried on load-bearing walls. In open districts where the risk of a direct hit is slight, such as industrial plants built in detached sections and the buildings are comparatively small, it is preferable to have a framed building with the walls monolithic with the frame and of sufficient strength and thickness to resist the effect of blast and splinters.

This is shown at B and C in Fig. 70. In this type of construction it would also be desirable to have a solidly constructed reinforced concrete roof made to a steep pitch or, where possible, conical in shape. This would deal with the deflection of the smaller bombs, the protective wall resisting the explosion on the ground outside.

On the other hand, when the probability of a direct hit is greater, as in cities with taller buildings more closely spaced, the safety valve type of construction indicated at A and D in Fig. 70 would appear to be more suitable.

In this case the maximum security against the effects of the explosion is obtained by the relief of internal pressure in a framed building hit by a bomb, due to the blowing out of the wall panels, as shown at D in Fig. 70. By this arrangement the minimum possible damage would be done to the building itself and repairs can be effected in the earliest possible time.

Just when to apply each type of construction must be determined after careful consideration of the specific circumstances, but it would appear to be wise generally to provide the heaviest fire-proof roof possible to deal with incendiary bombs, safety valve walls in the upper floors to provide relief

in the event of a direct hit by high explosive bombs of medium calibre and protective walls on the ground and first-floor storeys to deal with blast and splinters from bombs bursting at ground level.

To deal with the effects of blast pressures on structures, the Swiss recommendations state that the whole building should safely withstand a calculated wind load of 200 kg. per sq. metre, or approximately 40 lb. per sq. ft. over the whole area.

Damage at certain points may be expected, but the whole building would not collapse entirely.

In calculating the above resistance, any partitions less than 8 in. thick must be ignored.

The floor of the shelter, where not on solid ground, should be of solid reinforced concrete not less than 8 to 10 in. thick to resist splinters striking upward at an angle through the windows of the floor below, and should have reinforcement running in two directions at right angles.

Where the shelter is below ground but not on the lowest floor of the building, the floor should be of 6 in. concrete similarly reinforced.

Where a building has two or more floors below ground level, it is suggested that the sub-ground (*i.e.*, the floor immediately below ground floor) should be generally chosen for the shelter accommodation in order to reduce the risk from flooding, due to burst water mains or sewers. Moreover, this floor should, with suitable ventilation, be more easily kept free from heavy concentrations of gas than the basement below. In districts liable to flooding, due to damaged river banks or river walls, consideration should be given to preventing access to the building at all points. This may require that external basement courts should have solid parapets and that external doors or other openings which extend below the level to which floods may rise should be provided with suitable slots in the structure of the openings for the rapid insertion of tide boards in an emergency.

Earth Tremors

Earth tremors due to bombs produce seismic effects similar to those of earthquakes, and methods adopted in anti-seismic construction are likely to be effective.

The Swiss recommendations include the provision that multi-storey buildings must be capable of withstanding at each floor a horizontal load of at least one-sixteenth of the weight of the floors and other constructions above the floor under consideration.

In Japan the lateral force is taken at one-tenth of the gravity load, and it is claimed that buildings constructed to this standard are usually not more than 10 per cent. more costly than an ordinary structure of the same accommodation and shape.

SUMMARY OF CONSTRUCTIONAL PRINCIPLES FOR MAXIMUM RESISTANCE AGAINST HIGH EXPLOSIVE BOMBS

(a) Penetration

The effect is minimised by the use of heavy reinforced concrete roof and upper floors and is prevented by the provision of slabs of the thicknesses given in Table XII.

(b) Explosion

The effect is minimised by the deflection of the bomb to explode prematurely on detonating slabs conforming to the outline of the building.

Localisation is achieved by the use of heavy partition walls sufficiently strong to resist the blast pressure effects. Strong skeleton framed buildings with small exposed surface and with "safety valve" walls provide relief from internal or external explosive forces and minimise disruptive effects.

Strength and flexibility in the framework minimise permanent damage to the building. No defensive measures will prevent explosion of bombs.

(c) Air Suction Effects

The principles of protection against blast pressures are equally effective in minimising damage by air suction. Wire reinforced glass is no better than ordinary glass, which latter shatters to smaller and less dangerous pieces.

(d) Splinter Projection

See Table X.

Splinters weigh up to 3 oz. and may be of any shape.

They usually cut cleanly into concrete but crack brickwork badly and cause its collapse.

Homogeneous solidity is preferable to lamination.

Flexible mattresses of straw, sacking, metal wool and carpets provide considerable resistance to penetration by splinters and are more effective near the burst.

(e) Telekinesis Effects

The demolition effects of high explosive bombs are minimised by the use of building materials which disintegrate so completely that flying pieces cause little damage to neighbouring buildings.

Hard stone masonry is not so suitable as brick in this connection.

(f) Earth Impulse

Anti-seismic principles of construction can be suitably applied with the object of minimising the effects of earth impulse due to the explosion of H.E. bombs.

(1) The centre of gravity of the whole building should be kept low.

(2) Light-weight materials should be used in construction.

(3) The building should be strongly braced and framed.

Brick buildings are useless as they collapse. Timber buildings resist shock but are not fire resistant.

Steel-framed buildings unless specially strengthened at joints are not so suitable as monolithic reinforced concrete framed buildings which show the highest degree of resistance.

THE PROTECTION OF WINDOWS IN AIR RAIDS

Windows

Where shelter accommodation is provided on upper floors, the window area should not be greater than is required to provide normal lighting for peace-time use. The sills should be kept as high as possible in order to minimise the risk of

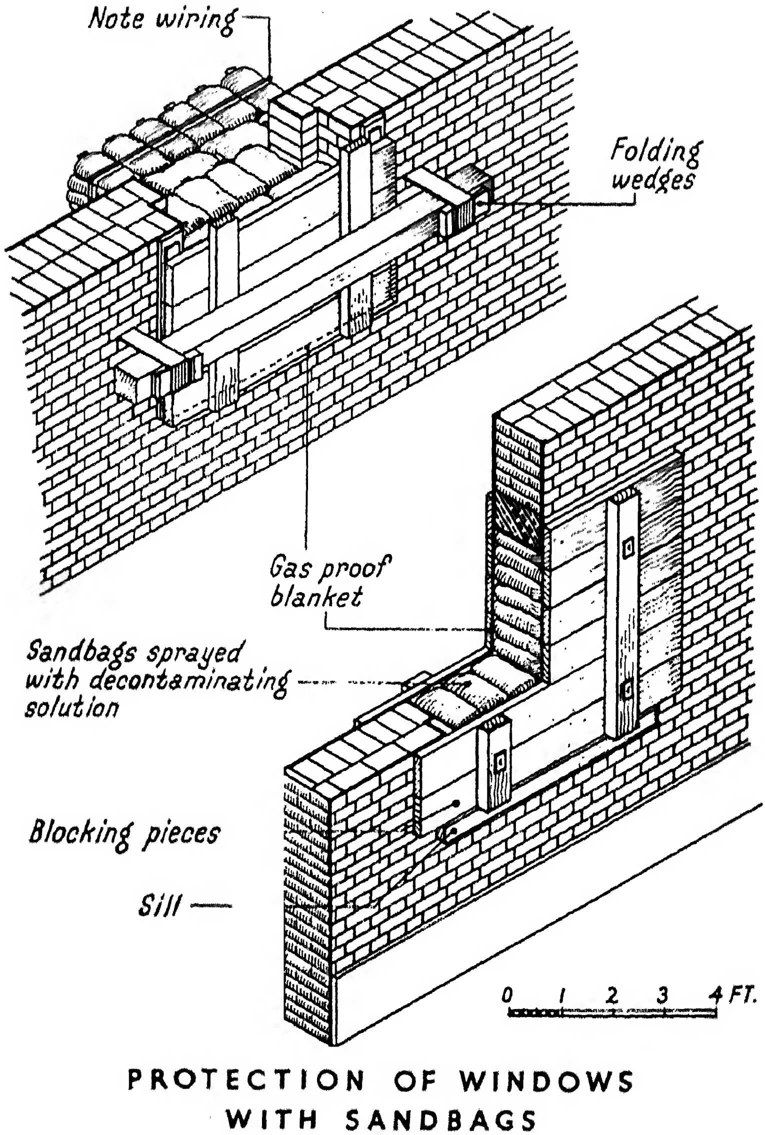


FIG. 71.—Protection of window opening with sand-bags.

splinters and the individual windows should be small in order to facilitate the provision of protective covering.

A window is a source of weakness in a building for the following reasons :—

1. Gas can enter through the joints, and in the case of badly constructed windows where the frame has not been sufficiently well bedded, between the window frame and the brickwork.

2. Splinters from bombs can pass through the glass, endangering the lives of the occupants and breaking the glass, thus allowing any gas to enter the room.

3. The blast pressure from high explosive bombs can shatter the glass, breaking it into small fragments, which are projected violently into the room. Dangerous cuts on the occupants may be inflicted and the gas-proofing of the opening will be destroyed.

Methods Recommended to Give the Highest Degree of Protection

Provided the glass remains intact, it is quite easy to prevent the entry of gas into the room by stopping up all cracks and crevices in the window and round the frame as shown in Fig. 24. This can be done by the use of putty, or a mush of paper pulp, and by pasting paper strips, or by sticking adhesive tape over all cracks and joints.

Complete protection against blast and splinters can be given by erecting a wall of earth or sand, 2 ft. 6 in. thick, on the outside of the window. The earth or sand can be contained in sand-bags, sacks, boxes, wooden or corrugated iron shuttering, or by any other available means. Such a wall to be effective should closely touch the building and should overlap the window opening by at least 12 in. all round (see Fig. 71).

When protection of this nature is properly provided, the glass will not be broken by blast or by splinters, and if the cracks and joints of the window are stopped up to prevent the possible entry of gas, the maximum available protection will be obtained.

Earth and sand give the best protection against the effect of blast, and are therefore most suitable for the provision of splinter-proof protection.

A protective wall of this nature will put the window out of action as regards its normal functions, for the duration of

hostilities, and in the case of upper storeys equally good protection can more easily be obtained by bricking up the opening altogether. [176]

Fig. 72 shows a type of steel shutter for the inside of window openings recommended for the splinter protection of essential plant, such as is adopted by the Office of Works at the Central Telegraph Exchange in London. The shutters were made by Messrs. Platt Bros. & Co. Ltd. at Oldham to the Office of Works designs, and cost from 23*s.* to 25*s.* per sq. ft., according to the kinds of material required for the tracks.

The largest superficial area for each sliding shutter is fixed at 15 sq. ft. in order to ensure that shutters can be quickly closed by the female staff.

Each shutter consists of five layers of ¼ in. mild steel strip riveted together, as indicated in the photograph, and runs on pulley track in a channel frame with guide pulleys at the top.

Shutters vary in height up to 4 ft. 9 in., the width for this height being limited to 3 ft. 2 in. When the wall brackets are at centres not exceeding 8 ft., the channel section is 3½ × 2 in., 4 × 3 in. channels being used on larger spans.

Tall windows are covered with four shutters in two tiers and single track.

It will be noted that the arrangement is not gas-tight, but if rubberised cotton fabric fixed on battens is wedged in the window reveal on the inside between the glass and the shutters all requirements are satisfied in a convenient and effective way. (See Fig. 73.)

ARMOURFLEX BLAST AND SPLINTER-RESISTING SHUTTERS

Fig. 75 clearly shows the components which together form a remarkably efficient protective shutter for windows, doors, entrances or exits. The Armourflex protective shutter is considerably lighter than one made of normal steel, which, although affording like protection from splinters owing to its greater thickness and weight, lacks resisting qualities against blast, fire and heat, and moreover presents difficulties in fixing because of the excessive weight and type of brackets essential to its support.

This shutter is unique in that it possesses resilience, provision

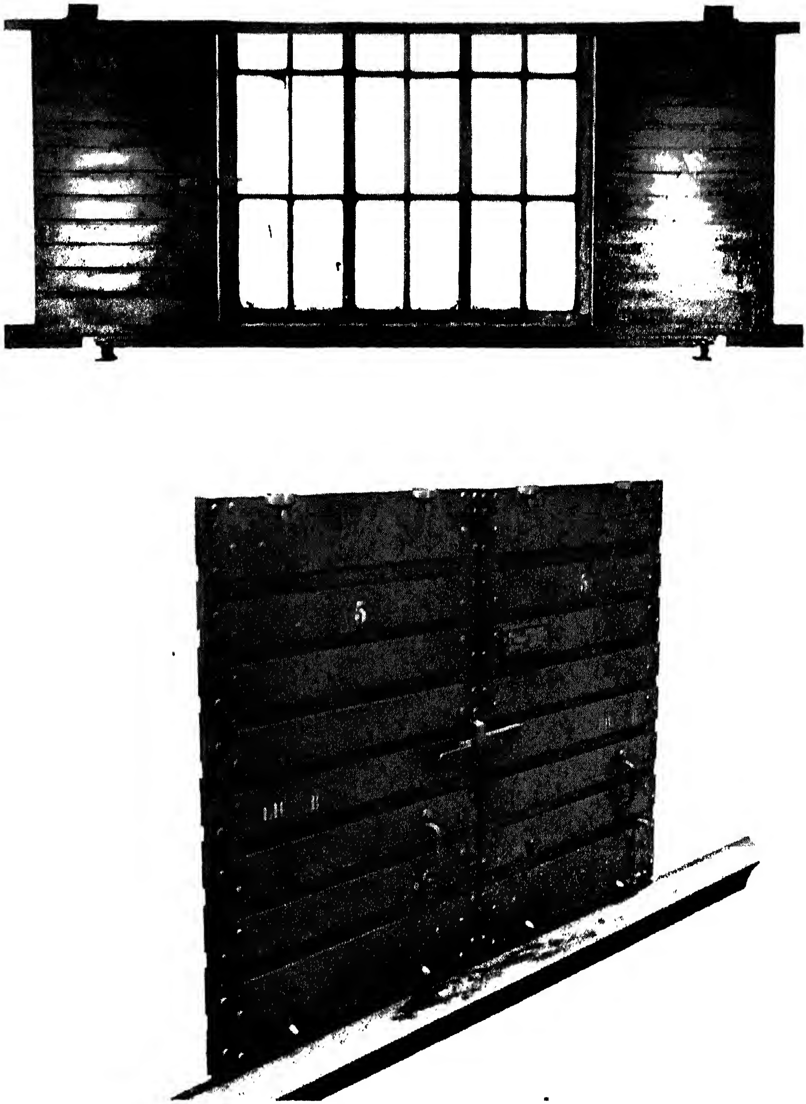


FIG. 72.—Office of Works type of sliding laminated steel shutters for windows.

[To face page 214.

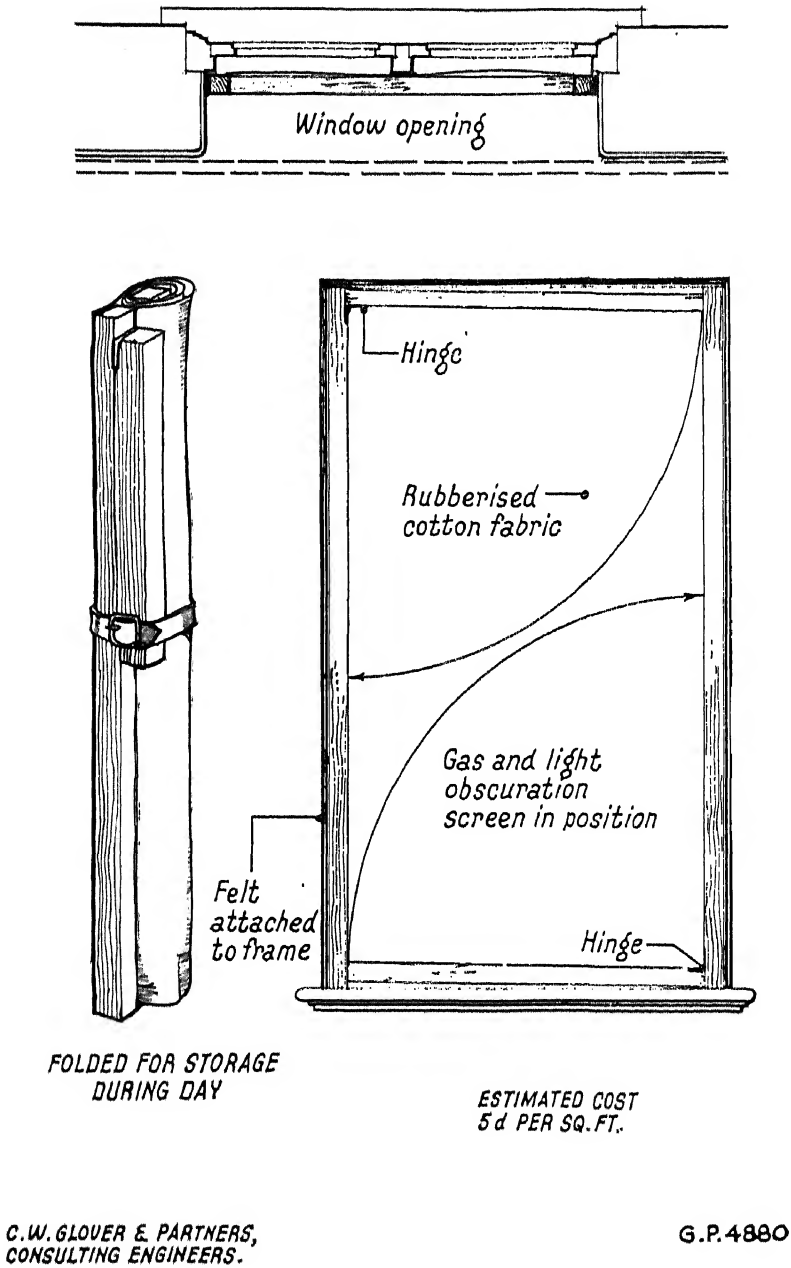


FIG. 73.—Gas- and light-tight portable shutter for inside of window opening.

being made for it to flex under blast pressure: the shock from an explosion or impact from shell and bomb splinters being distributed over its entire surface.

Tests on the Armourflex sheet steel have shown its remarkable bullet-resisting properties. Twenty gauge Armourflex

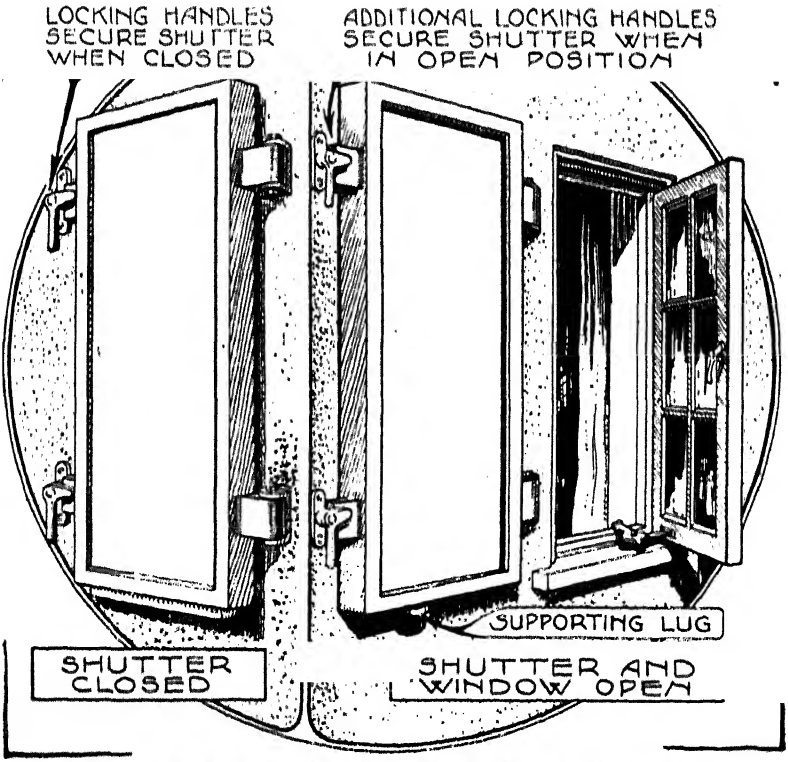


FIG. 74.—Arrangement of Armourflex splinter-resisting shutter.

sheet steel stops a 0·45 heavy automatic at 5 yards range, whereas under identical conditions this bullet penetrates ordinary mild steel of two and a half times the thickness.

Note the muzzle velocity of this bullet is 870 ft. per second.

The heavy duty type H Armourflex shutter safely resists the impact of a 0·303 service pattern bullet fired point blank at 15 yards range—the muzzle velocity of this bullet being 2,450 ft. per second—more than twice that of sound.

The use of this shutter saves 140 per cent. in weight as against normal steel of equivalent strength.

Fig. 74 shows an arrangement of window shutters which can, of course, be designed to operate in any convenient way or be arranged as doors or exit shutters.

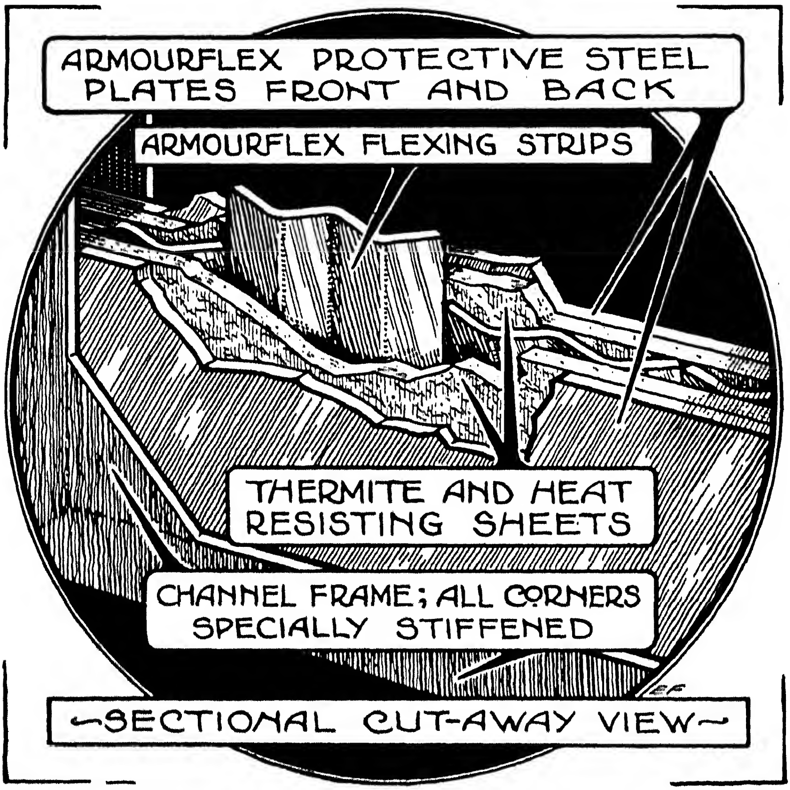


FIG. 75.—Sectional view of Armourflex shutter.

For maximum safety and economy the strength of shutters should be designed to equal that of the wall to which it is attached up to the maximum thickness required in the circumstances.

Armourflex Shutter Type R

Extra Light Duty. For covering lantern lights, skylights, deadlights, rooflights and light wall partitions. This shutter is lined with a single thermite and heat-resisting sheet.

Armourflex Shutter Type L

Light Duty. For fitting to solid brick walls up to 4½ in. thick or unreinforced concrete up to 5 in. thick.

Armourflex Shutter Type M

Medium Duty. For solid brick walls 9 in. thick, 11 in. cavity brick walls, or unreinforced concrete 10 in. thick.

Armourflex Shutter Type H

Heavy Duty. For solid brick walls 13½ in. thick, 15½ in. cavity brick walls, or unreinforced concrete 15 in. thick.

Armourflex Shutter Type EX

Extra Heavy Duty. For all walls in excess of the thicknesses given above.

TABLE LXVI

Shutter Type.	flex Steel. Size.	flex Steel. Weight.	Weight of Normal Steel Similar Strength and Size.	Weight Saved.
R. Extra light duty .	6′ × 3′	56 lb.	92 lb.	67½ per cent.
L. Light duty . .	6′ × 3′	84 ,,	180 ,,	120 ,,
M. Medium duty .	6′ × 3′	120 ,,	308 ,,	202 ,,
H. Heavy duty .	6′ × 3′	230 ,,	552 ,,	140 ,,
Ex. Extra heavy duty.	6′ × 3′	400 ,,	1,104 ,,	140 ,,

TABLE LXVII

	£	s.	d.	
4 × 2 ft. light shutters L and fittings . .	6	0	0	each.
,, medium ,, M ,, . .	8	0	0	,,
,, heavy ,, H ,, . .	12	0	0	,,
6 × 2 ft. light doors and frames, including fittings. With Armourflex one side, M.S. the other. Weight 90 lb.	8	10	0	,,
,, light doors and frames, including fittings, with Armourflex two sides. Weight 58 lb. . . .	11	0	0	,,
,, medium doors and frames, including fittings	21	0	0	,,
,, heavy doors and frames, including fittings	30	10	0	,,

Armourflex shutters are supplied by Greenwoods Ventilating Co. Ltd. at the approximate prices given in Table LXVII for the shutters delivered in the metropolis, but not fixed.

Methods which Give Lesser Degrees of Protection

When the splinter-proof protection is some distance from the window with the object of admitting light, no protection against blast is afforded. In such cases and also when no splinter-proof protection has been provided at all, as in the upper storeys of buildings, it will be necessary to provide :—

1. Means of preventing the admission of gas owing to the breaking of the glass.

2. Means whereby glass splinters are prevented from being hurled violently into the interior.

1. Gas Protection after Glass has been Shattered

The window opening must be blocked by some sort of shield, complying with the following essential points :—

(*a*) It must be gas-tight, and when fixed must make a gas-proof joint with all sides of the window opening.

(*b*) It must be capable of being fixed promptly by the occupants of the room.

(*c*) The fixing must be secure to ensure that the shield will not be blown in by the blast of bombs, and the material of which it is made should be of sufficient resilience to withstand instantaneous blast pressures up to 35 lb. per sq. in. The type of shield selected must depend on the shape and also on the window opening, but the following are various methods available :—

(i) A wood frame, made accurately to fit the window opening on the inside, is pressed against the window frame by means of thumbscrews fixed at suitable intervals, with a strip of felt or rubber between making a gas-tight joint. In this movable frame are fixed two layers of blanket material reinforced with wire-netting on each side (½ in. mesh). The boltholes in the movable frame should be a good deal larger than the bolt itself to accommodate distortions in use, and the thumbscrews on the bolts should only

be pressed home sufficiently tightly to make a gas-tight joint.

(ii) A curtain of gas-proof material can be kept rolled up at the top of the windows. If the glass is broken it can be let down and secured to the window frame or the architrave of the window opening, using battens and thumbscrews.

(iii) An old piece of carpet, cut to the size of the window opening, can be nailed to the window frame where the frame is of wood. This should be sprayed with fresh decontaminating solution.

(iv) A sheet of 5-ply wood, large enough to cover the whole window opening, can be drilled to suit thumbscrews securely fixed in the wall.

If the inner surface of the board be sprayed with a thick coating of rubber solution, a gas-tight shield will be provided when the board is screwed into position.

(v) Plywood shutters with feet attached to the rims, made so as to have a friction fit in the opening, have also been suggested as a protection from gas entry. Under blast pressure they are forced bodily into the room and must be replaced.

(vi) The Office of Works has provided light wood frames on the inner face of the window opening forming a felt-covered reveal. Within these frames light shutters are held in place with ball catches at the sides and at the top by rubber shock absorbers 9 in. long and about $\frac{3}{8}$ in. diameter.

The shutters are constructed of light wood frames braced diagonally and covered on one side with close mesh wire-netting and on the other with 2-ply rubberised cotton fabric. These shutters catch flying glass, provide light obscuration, but yield to blast without damage. They then hang on the rubber suspension convenient for re-fixing. (See Fig. 76.)

(vii) Fig. 77 shows a window protection arrangement comprising a splinter mattress of metal wool hung outside the window opening and a folding gas-proof shutter on the inside.

(viii) Fig. 78 shows a combination of Crittall standard inward

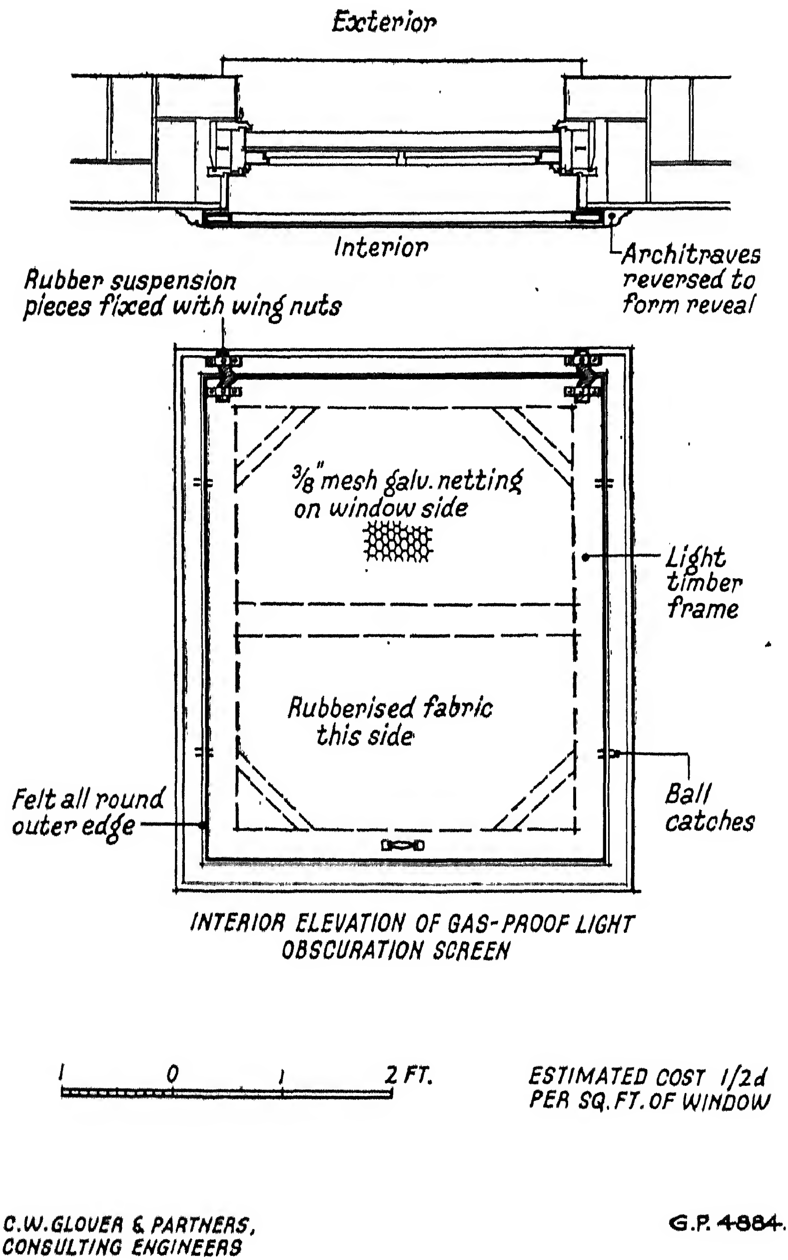


FIG. 76.—Method of gas proofing window with light-obscuring and glass-arresting screen which yields to blast pressure and is therefore more likely to survive bombardment.

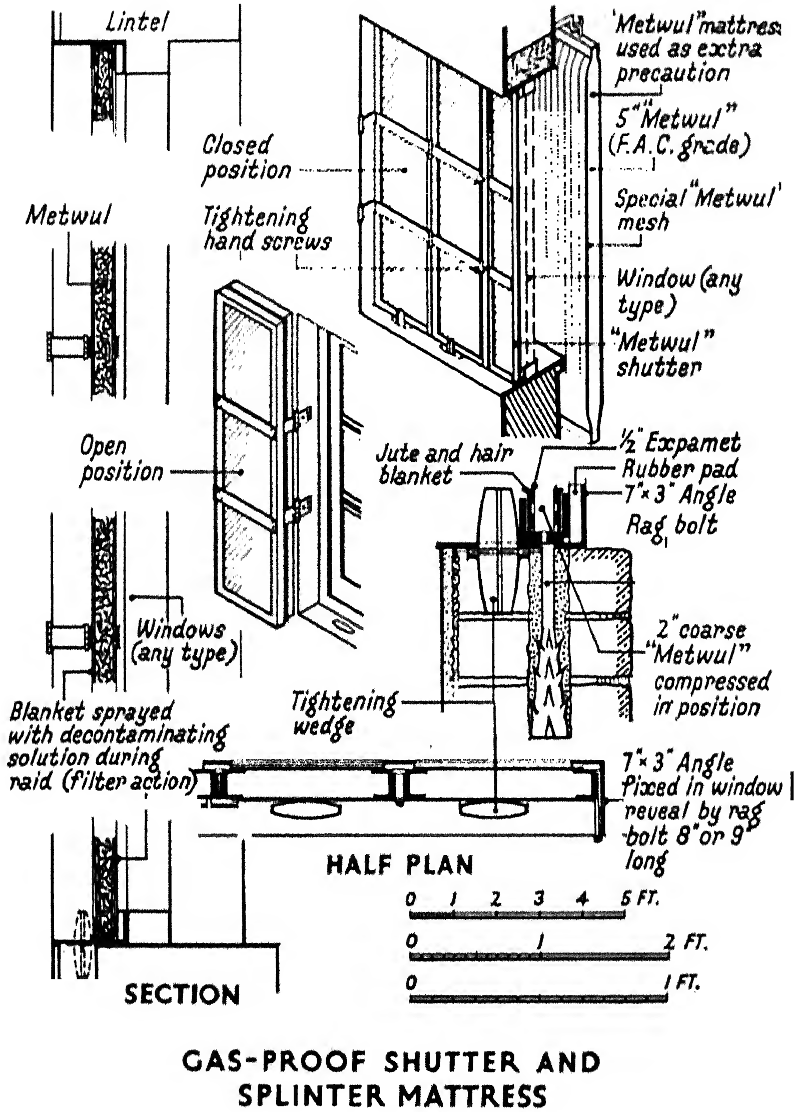


FIG. 77.—Window protection suitable for use in the upper storeys of important buildings. The mattresses are hung outside the windows in an emergency.

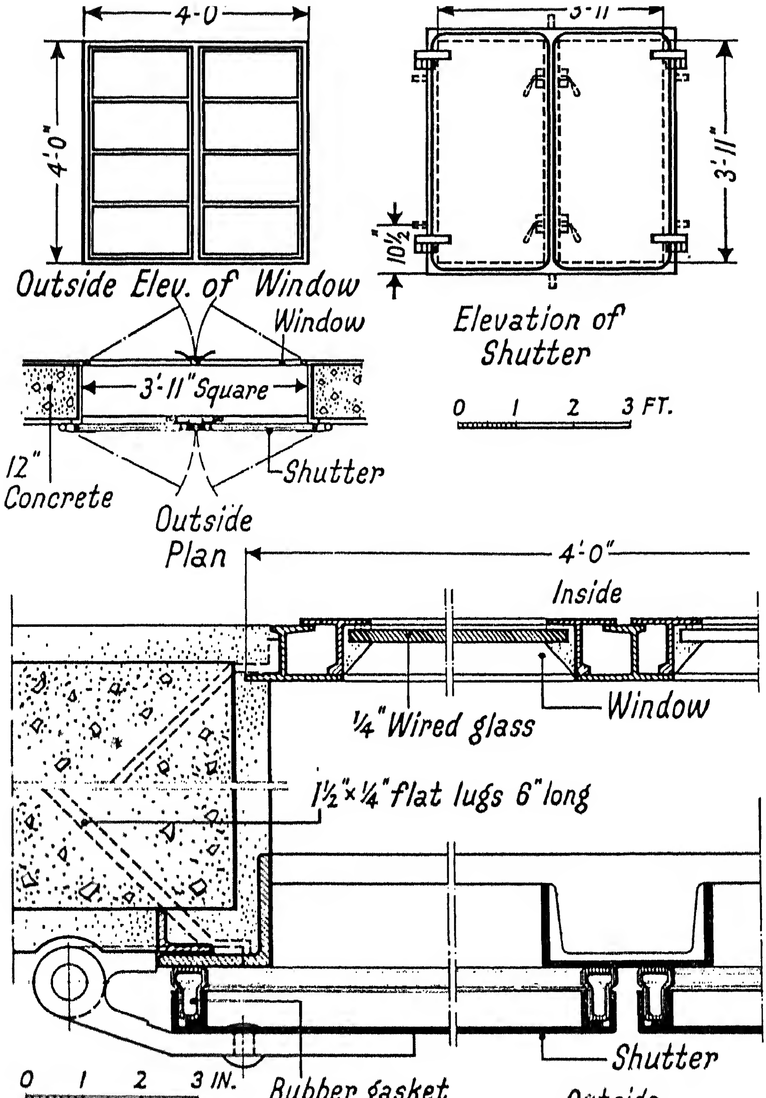


FIG. 78.—Crittall's blast-resisting and gas-proof folding window shutters hung on outside of opening with inward opening steel casements.

opening window with gas-proof splinter-resisting shutter on the outside.

Splinter-proof protection by this means involves the use of very heavy shutters.

(ix) When the maintenance of window light is essential, the whole window opening can be blocked up solid with glass bricks to the full thickness of the wall.

This provides gas-proof protection, together with a reasonable degree of blast-proofing and splinter protection. The additional use of the splinter mattress shown in Fig. 77 improves the arrangement.

2. To Prevent Glass Splinters from being Projected into the Room

(i) The window can be glazed with "Laminated" glass, which should be $\frac{4}{10}$ in. thick for small panes not exceeding 1 sq. ft. in size. It should be thicker if used in larger panes. Laminated glass will stand up to blast pressure if securely fixed in the frame. It may crack, but the celluloid sheets within the glass will remain intact and still keep the window gas-proof. It should be noted that "Laminated" glass and not "Toughened" glass must be used, as the latter will not answer the purpose.

(ii) The glass can be replaced by a non-inflammable celluloid material, of which there are a variety of makes, $\frac{1}{10}$ in. thick. This should be reinforced by $\frac{1}{2}$ in. mesh wire-netting fixed rigidly to the window frame and in close contact with the inner surface of the celluloid.

This arrangement will also withstand blast pressure.

(iii) Super-Armourbex is a clear non-flammable cellulose-acetate sheet reinforced in the interior with $\frac{1}{2}$ in. mesh of steel wire welded at each intersection. It is $\frac{80}{1000}$ in. thick and is exceptionally transparent for material of this kind. Such a material would not fly in jagged splinters under explosion pressure, and is therefore very suitable for the "glazing" of windows. Sheets 61. × 27 in. are supplied by the British Xylonite

Co. Ltd. at 31*s*. 6*d*. per sheet. It can be cut with strong scissors.

(iv) Armourbex is Bexoid $\frac{22}{1000}$ in. thick reinforced with wire gauze, and is suitable for application to the inside of window glass with a transparent cement supplied by the above company, who manufacture sheets 55 × 24 in., price 10*s*. each.

(v) Bexoid, $\frac{3}{1000}$ in. thick, in sheets 35 × 24 in. (3 oz.), price 6*s*. per lb. or 1*s*. 6*d*. per sheet, is also supplied by the British Xylonite Co. This material can easily be stuck on to window glass with a new type of varnish perfected by the company.

(vi) British Cellophane Ltd. are now producing two A.R.P. rolls of "cellophane." One grade is for household use, and requires to be fixed to windows with a good clear gum or liquid glue (which may be improved by the addition of 10 to 15 per cent. of glycerine), and the second is especially designed for institution, office or factory use.

This material is already coated with adhesive, and only requires immersion in water prior to its application to glass, to which it quickly adheres.

(vii) Various materials can be stuck on to the glass. This will not prevent the glass from being broken by blast pressure, but will reduce the risk from flying splinters of glass.

These materials are given below in order of merit :—

(*a*) One of the transparent non-inflammable materials commonly used for wrapping purposes.

(*b*) Linen fabric (such as is used for pillow-slips).

(*c*) Mosquito netting.

(*d*) Stout paper.

Ordinary gum can be used for sticking the above on to the glass, though in the case of the transparent wrapping material it should be inspected frequently, as the material is apt to lift and may require re-gumming. As an alternative, water-glass is recommended as an adhesive for wrapping material.

It should be noted that windows protected as suggested in (2) above are vulnerable to splinters.

GAS-PROOF WINDOWS

Fig. 79 shows full-size details of Williams and Williams gas-proof windows, and Fig. 80 the standard outlines thereof.

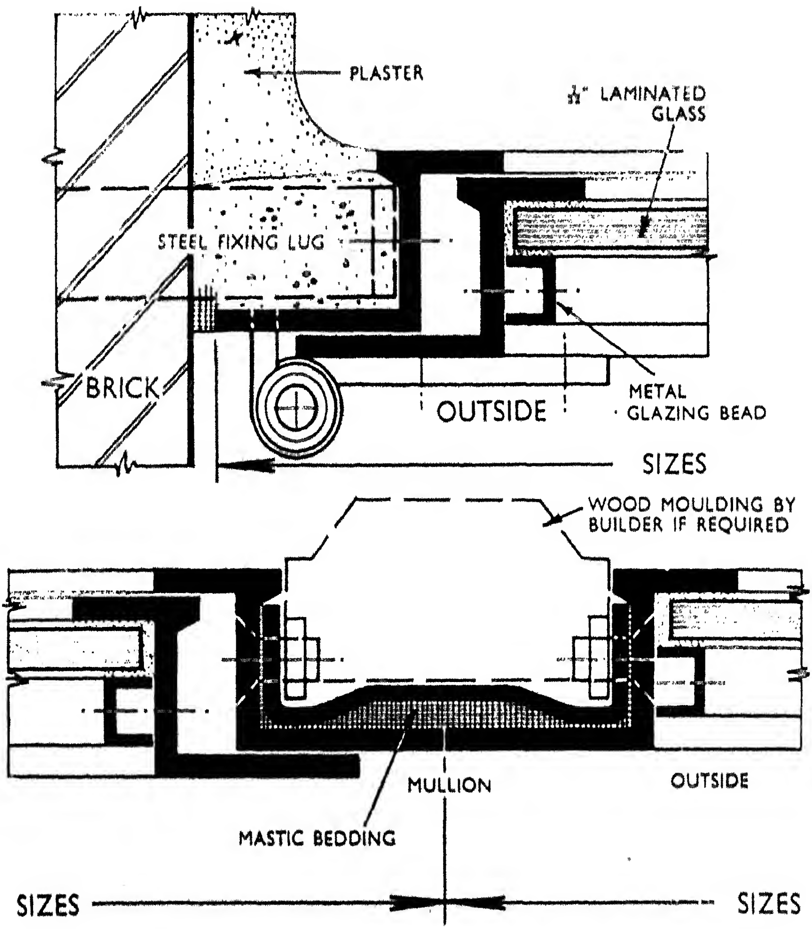


Fig. 79.—Full-size details of Williams and Williams gas-proof windows.

Specification

This range of standard residential type windows is rendered completely gas-proof by the application of " Densyl " plastic

sealing material to the flat meeting surfaces, and when fitted with $\frac{7}{32}$ in. laminated glass and metal glazing beads, will withstand a certain amount of blast.

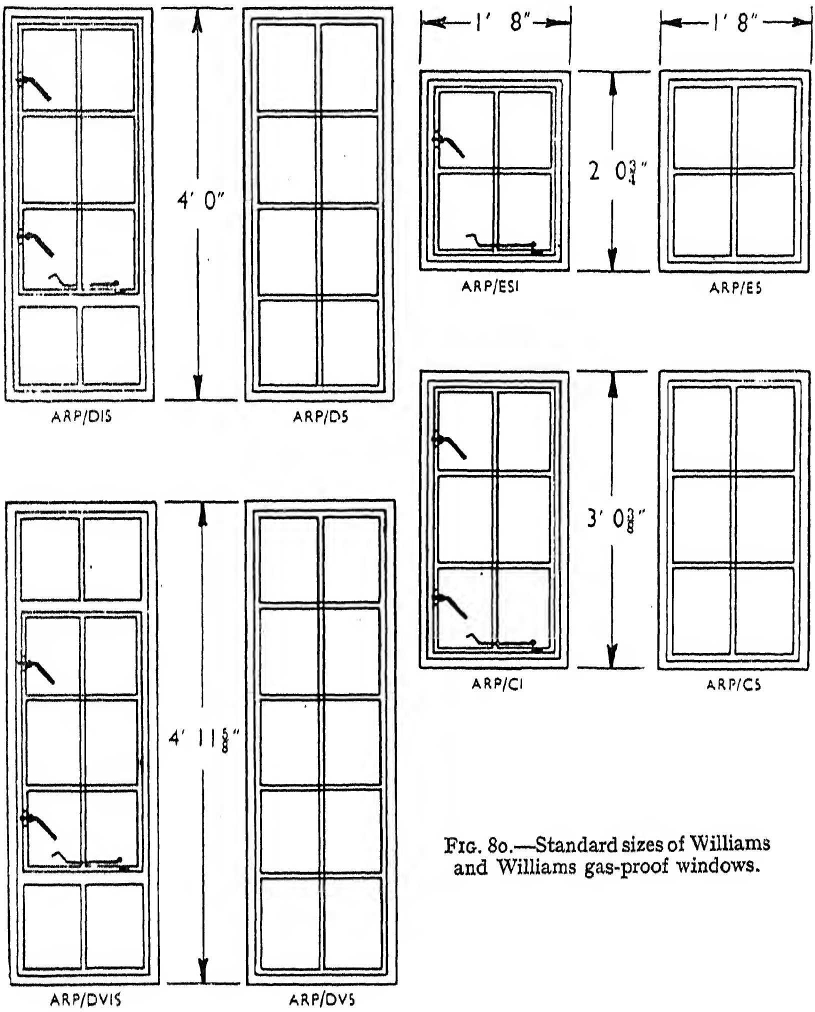


Fig. 80.—Standard sizes of Williams and Williams gas-proof windows.

The windows are constructed so that an extra wide contact surface is obtained, ensuring a perfect gas seal when the "Densyl" is applied.

The range includes fastlights in the same section to allow

composite windows to be formed. Handles and pegstays are in bronze and are of normal pattern.

These windows give a similar appearance to that of the ordinary range of wide frame standard residential type windows, and can be used in conjunction with these types.

Fixing holes are drilled $4\frac{1}{2}$ in. from each corner, D and DV types being provided with an additional hole 1 in. above centre in each jamb member. Lugs for fixing to brickwork or screws for fixing to wood are supplied free of charge.

PAVEMENT LIGHTS

Horizontal pavement lights of glass prisms may be said to withstand blast pressure if they are very securely fixed in their framework.

Vertical stallboard lights of similar construction will resist blast pressure in the same way, but are vulnerable to splinters.

If these prisms are not very securely fixed into their frames, in all probability they will be projected, if subjected to blast pressure, with considerable force into the building.

The protection of pavement lights by earth or sand in sandbags, boxes, etc., will assist in distributing the blast pressure impulse in both cases, and will protect the glass from damage by splinters in the case of vertical lights, and against falling masonry in the case of horizontal lights (see Fig. 68).

DOORS TO SPLINTER-PROOF AND BOMB-PROOF SHELTERS

The weakest part of an air raid shelter is normally the door or emergency exit. The full requirements of doors to splinter-proof and bomb-proof shelters may be enumerated as below :—

1. They should be of fire-resisting construction.

2. They should be proof against the penetration of splinters from 500 lb. fragmentation high explosive bombs exploding not closer than 50 ft. from the door (see Recommendations, p. 38).

3. They should be blast-proof and capable of withstanding an equivalent static air pressure of 10 lb. per sq. in. over the whole of the area of the door and a suction of twice this amount.

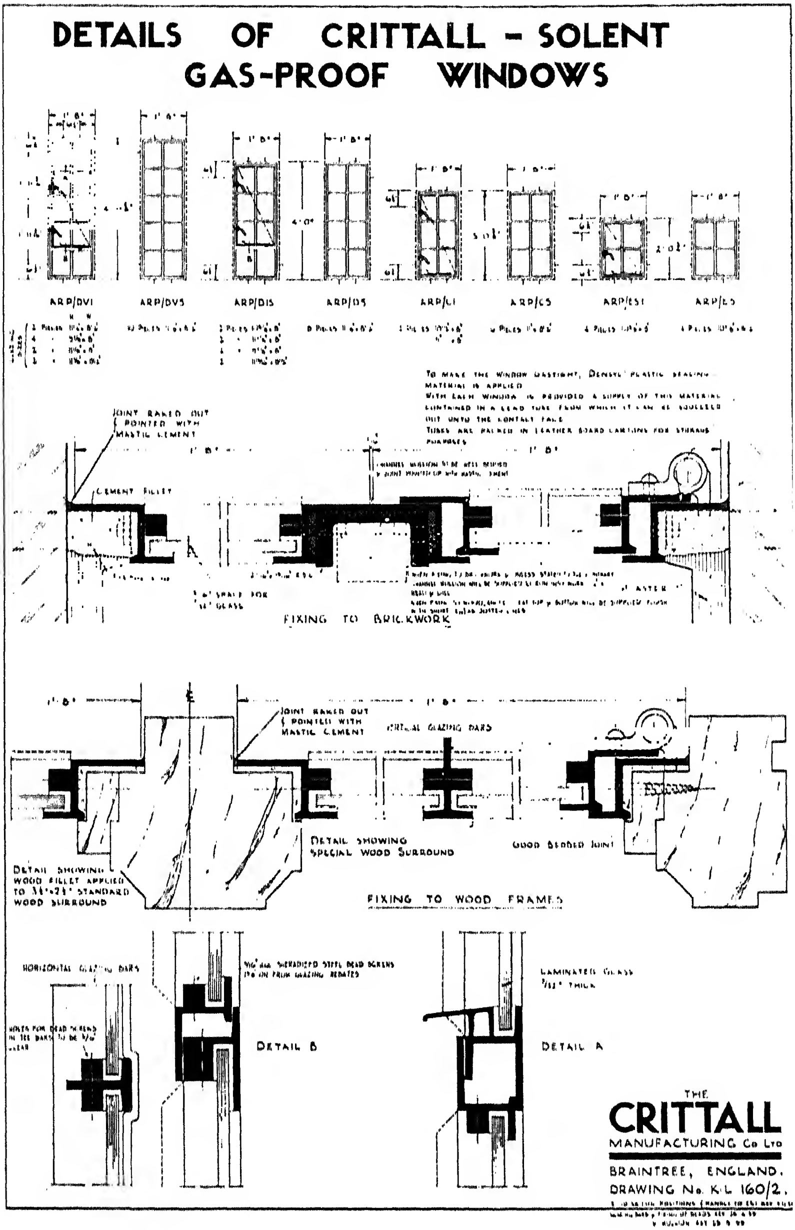


FIG. 80A.—Details of gas-proof windows.

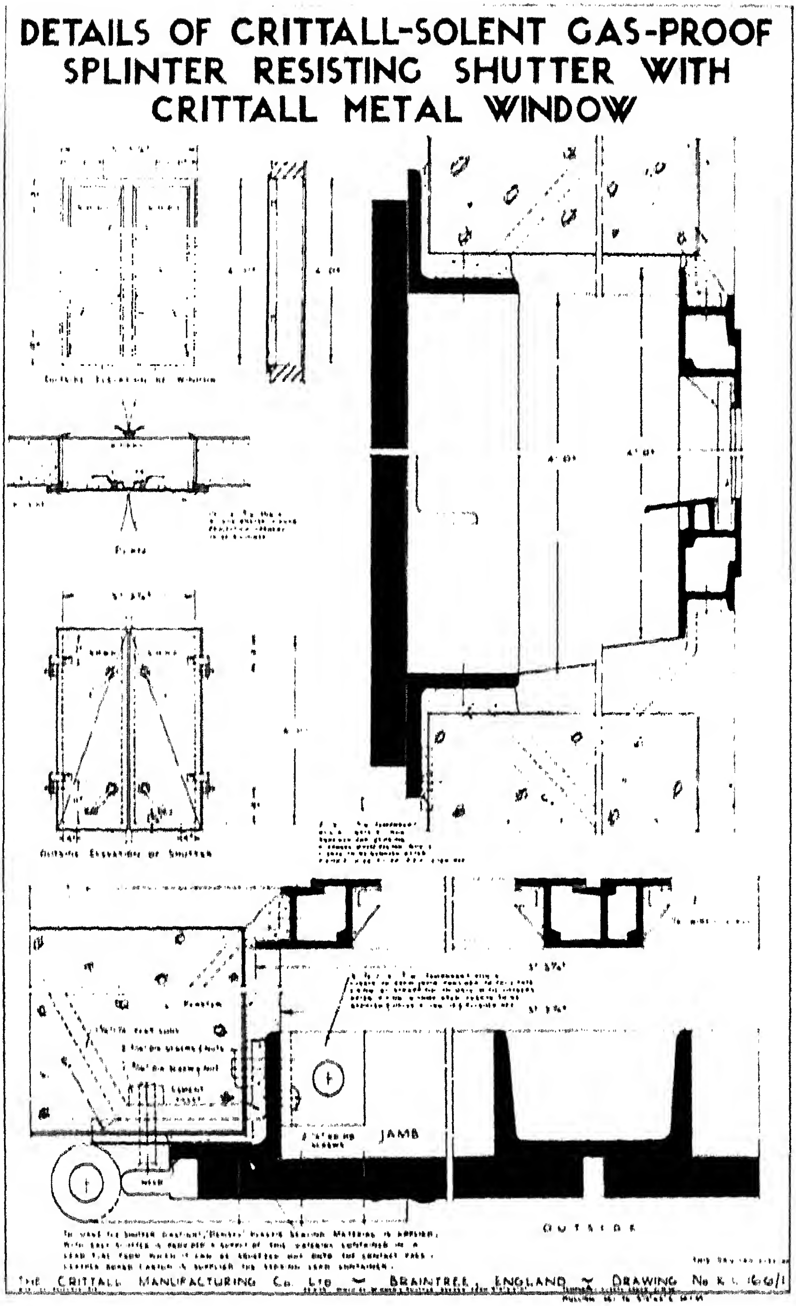


FIG. 80B.—Splinter-resisting window shutter.

4. They should be gas-tight and all seatings and gas checks should be readily renewable.

5. They should be water-tight and capable of withstanding water pressure up to 10 ft. head.

6. They should open inwards. *Note.*—Recent experience on the Continent has shown that doors opening outwards are often blocked by *débris*, and occupants are thus unable to leave the shelter until rescued.

7. They should be capable of being opened and closed from each side of the door.

8. They should be provided with an inspection port fitted with a blast-proof cover on the outside which can be operated from both sides. The transparent " glazing " should be fire- and splinter-proof.

9. The door locking and wedging devices should be on the *inside* of the door protected against damage by splinters or *débris*.

10. The doors should be as small as convenience in use will permit.

11. They should be installed some distance *above* the floor of the shelter and of the passage outside to minimise entrance of water and gas during operation.

There is considerable justification for the argument that doors to shelters ought to be as light and as flimsy as ordinary gas-proofing requirements will permit, and that unless a strong-room type of door be adopted it is not possible to provide a door of adequate strength to resist blast and splinters.

There is no doubt that all doorways should be " blinded " with splinter-protecting walls or revetments and that entrances should be large enough to afford easy access with the minimum of delay.

Entry to Shelters

The degree of protection afforded by a shelter depends upon its accessibility as well as on its strength, and whatever type of shelter be adopted the entrance to it should be clearly marked by day and by night.

The rate of entry into a shelter will be affected by such complicated factors as darkness, hindrances at air locks, slow progress of old and infirm people, wounded and stretcher cases.

The internal arrangements in the shelter, intensity of lighting, etc., also govern the rate of entry.

From the "Manual of Safety Requirements in Theatres" it will be seen that a unit width of 22 in. is considered the minimum which will allow the largest person, or a woman leading a child, to pass in comfort, and that 40 persons per minute can pass an exit per unit of exit width.

In public shelters [5] no entrance should be narrower than two units nor wider than eleven units of 22 in., and wide entrances should be divided by barriers into lanes.

Entrances	40–55	in.	wide	count as	2	units.
,,	56–75	,,	,,	,,	3	,,
,,	76–100	,,	,,	,,	4	,,
,,	101–125	,,	,,	,,	5	,,

The Metropolitan Police have observed that crowds leave football grounds at the average rate of 25–30 per foot width of exit per minute, whilst the L.P.T.B. have observed unhurried crowds on stairs and entrances pass at about 40 per ft. per minute for the 1 unit width, and only 25 per ft. per minute in the wider openings of 3 units.

The Home Office recommend in "Structural Defence" an allowance of 40 persons per unit width of shelter entrance per minute. Thus for 4 ft. width of entrance the persons per minute would be 80, and for 7 ft. entrances 160 per minute.

Fig. 81 shows the frame and the interior of a Hobbs-Hart blast-resisting, gas and water-tight door of substantial construction. This door has a plate 1½ in. thick in solid steel, but can, of course, be made to any thickness. It is hung in a steel channel frame to take the effect of blast from either side, closes on to a renewable compressible seating, and is compressed against it by a series of steel wedge bolts operated by a hand wheel from either side. The door swings about two centres to ensure uniform compression.

Single-leaf doors giving a clear way of 6 ft. 6 in. by 3 ft., hung in a frame formed of 12 in. by 4 in. steel channels, cost in the neighbourhood of £70, depending upon any departures from standard.

Blast-resisting and fire-proof doors made of durasteel are illustrated in Fig. 82.

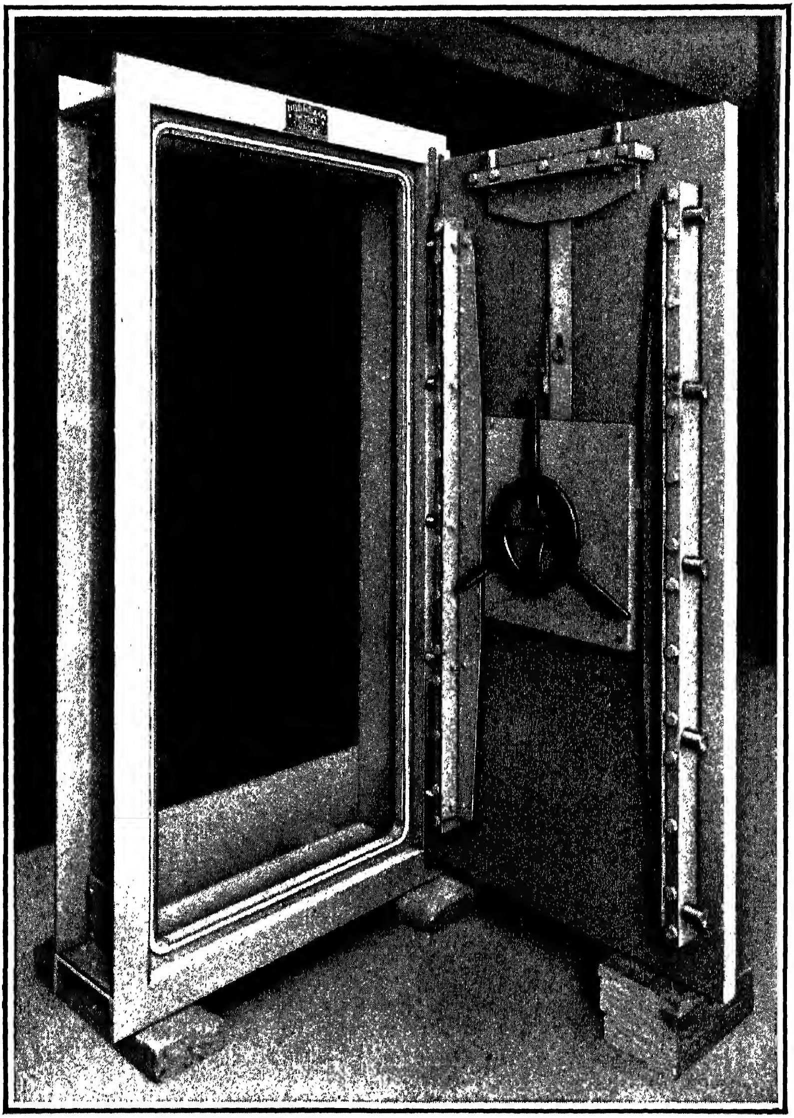


FIG. 81.—The Hobbs-Hart blast-resisting door. Gas- and water-tight.

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FIG. 82.—Blast-resisting and fireproof doors of Durasteel.

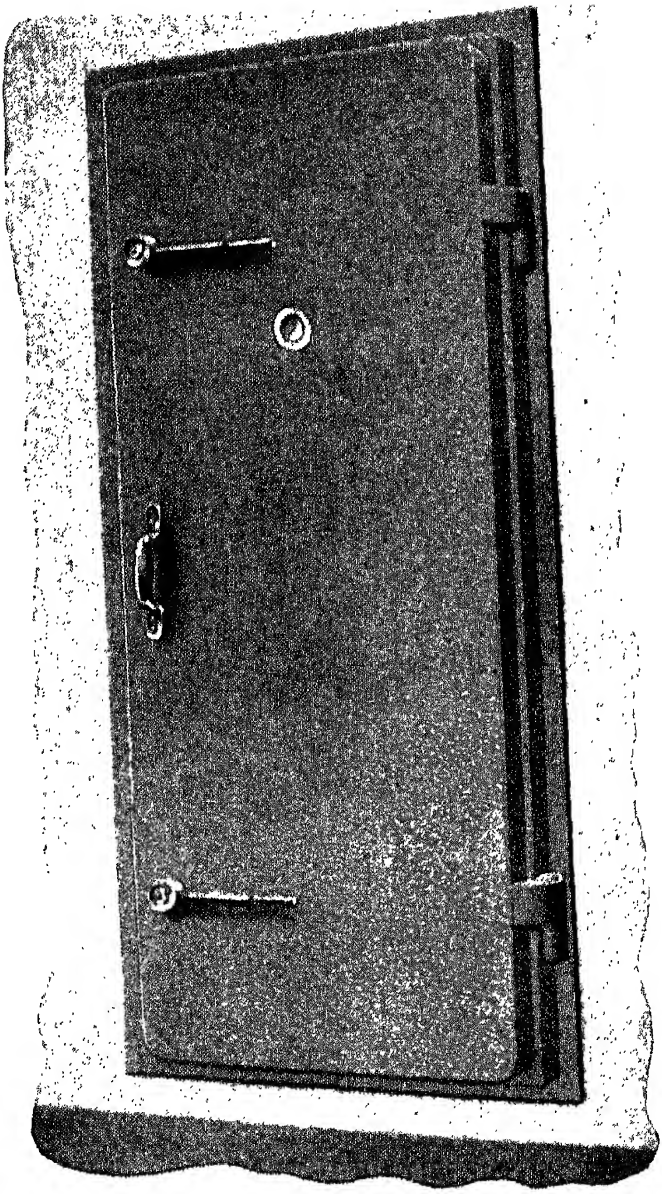

FIG. 83. The Chatwood gas-proof door.

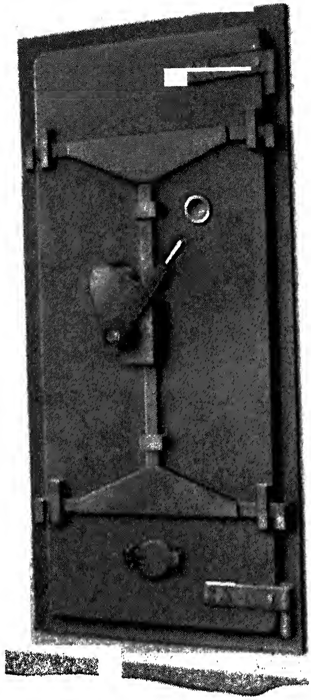

FIG. 84.—The Chatwood gas-proof, blast and splinter-resisting door.

The lighter doors are composed of two layers of durasteel impact sheets, covered with $\frac{1}{8}$ in. steel sheet and protected with 3DF2 durasteel exterior sheets, making a total thickness of $1\frac{1}{2}$ in.

The heaviest section has multiple steel plate cores with fibrous impact absorbing sheets, the overall thickness being 3 in.

Messrs. Milner's Safe Co. Ltd. supply a light gas-proof and splinter-resisting door constructed of $\frac{1}{4}$ in. solid M.S. plate with 4 in. by $\frac{1}{4}$ in. styles and rails on outside making door edge $\frac{1}{2}$ in. thick. The frame is of $2\frac{1}{4}$ in. by $2\frac{1}{4}$ in. by $\frac{1}{4}$ in. angle, and the "peephole" is 3 in. in diameter, and is fitted with armoured plateglass.

The door is rendered gas-proof by compression on to a rubber seating, which can be omitted if desired.

THE CHATWOOD GAS-PROOF DOOR

This door is for gas-tight qualities only, and it incorporates the following features :—

Gas-tight qualities achieved by the two individual clamps operated from both sides of the door, with a rubber seating which can be quickly renewed.

Spyhole in a gas-tight seating.

Door plate 18 G.

Bracket to enable the door to be levered off its hinges in emergency.

The clear opening is 6 ft. 3 in. high by 2 ft. 6 in. wide.

Price £25. (See Fig. 83).

THE CHATWOOD GAS-PROOF, BLAST AND SPLINTER-RESISTING DOOR

This door incorporates the following features :—

Rapidity of operation, and for this a central lever enables the clamps to be operated from both sides of the door, if necessary.

Hinges which permit a perfect seal.

A rubber seating for gas-tight qualities which can be readily replaced or renewed.

A spyhole in gas-tight seating.

A scouring opening, and this is also in a gas-tight seating.
Special hinge arrangement permitting of the removal of the rubber seating and providing a metal-to-metal joint.

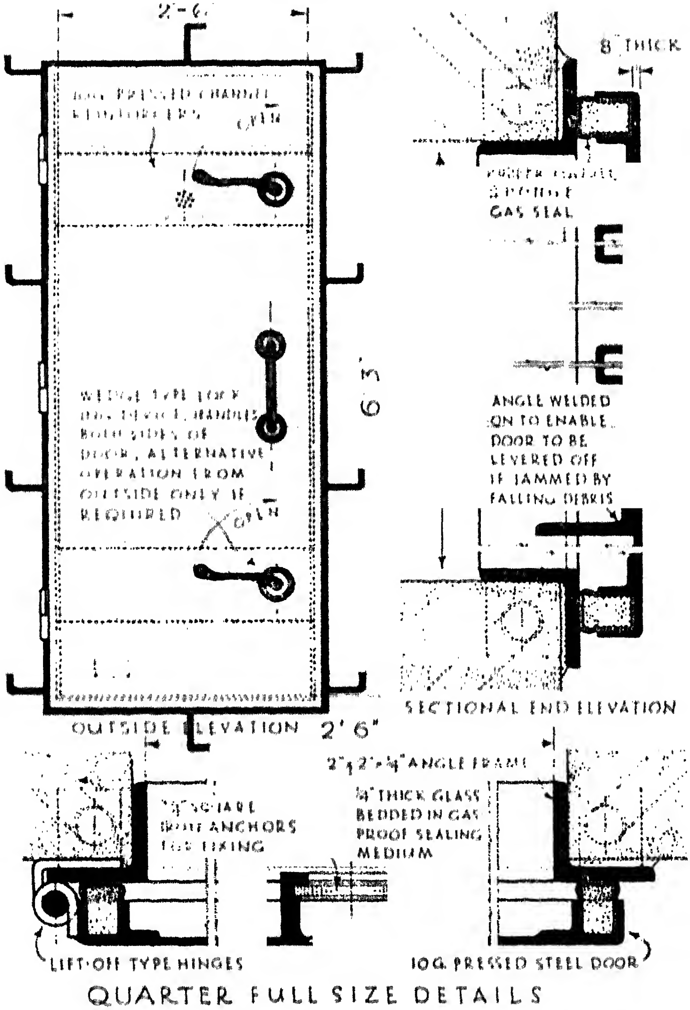

FIG. 85.—Hope's G.1 ⅜-in. gas-proof door. Price £9 15s.

Door plate ⅜ in. thick.
Bracket to enable the door to be levered off its hinges in emergency.

The door has a clear opening 6 ft. 3 in. high by 2 ft. 9 in. wide. Weight 6 cwt.
Price £30. (See Fig. 84).

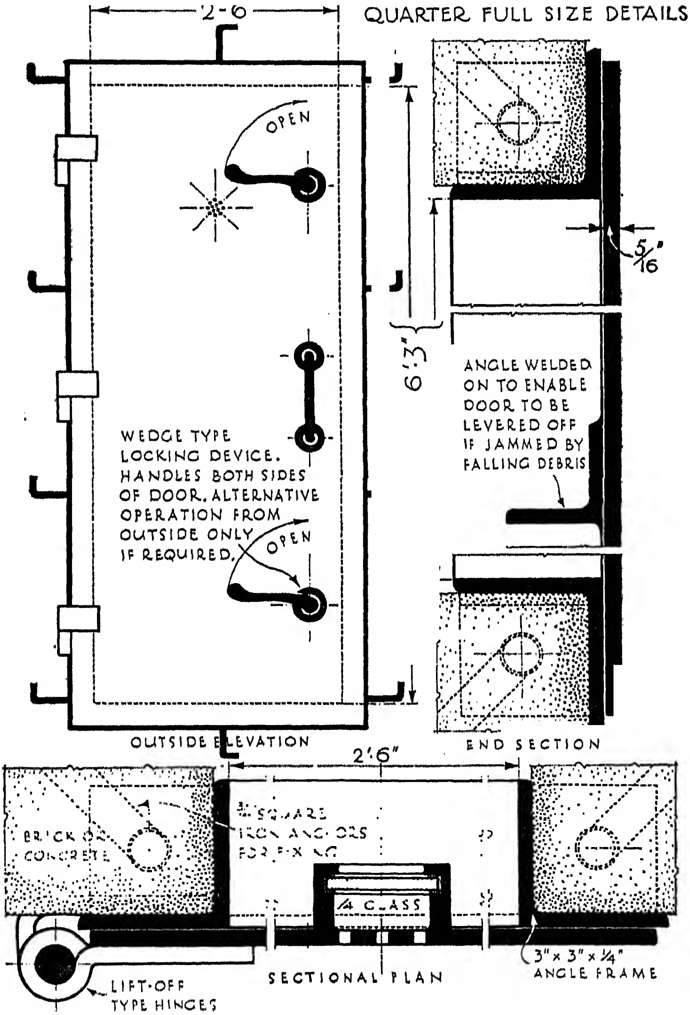

Fig. 86.—Hope's Type S.1 $\frac{5}{16}$-in. splinter-resisting door. Price £10 5*s*.

Messrs. Williams & Williams supply a 6 ft. 3 in. by 2 ft. 6 in. by 12 G. M.S. plate gas-proof door at £9 10*s*., and 6 ft. 3 in. or 5 ft. 6 in. by 2 ft. 6 in. or 2 ft. by $\frac{1}{2}$ in. M.S. plate splinter-

resisting and gas-proof door with framing angles and fixing lugs.

Metal to metal contact is provided on all sides with a $1\frac{1}{4}$ in.

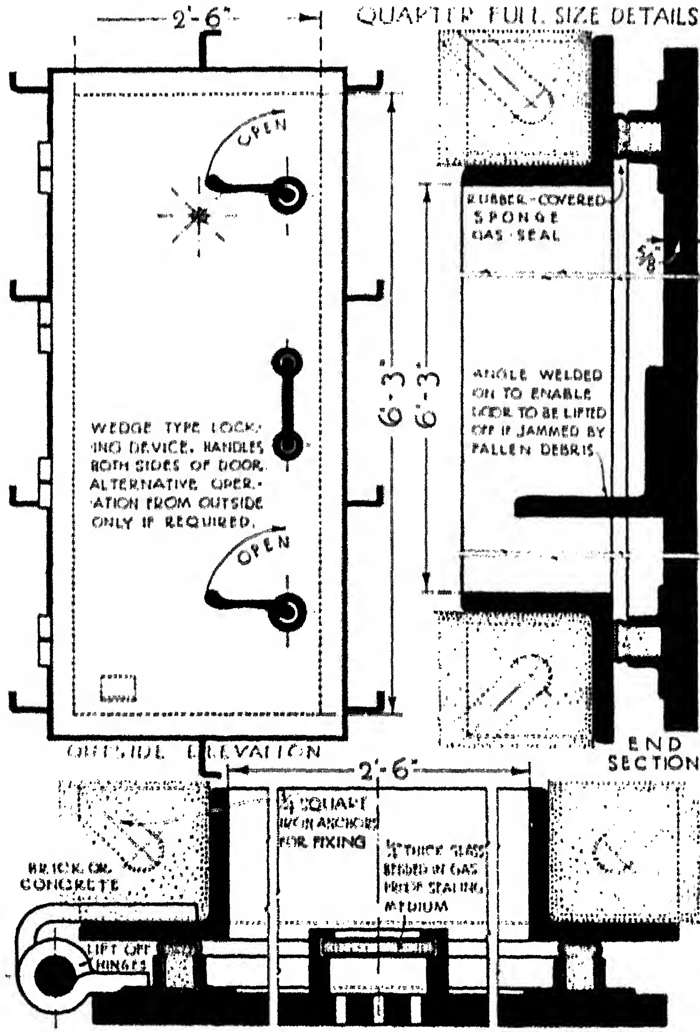

Fig. 87.—Hope's G.S.2. $\frac{3}{8}$-in. splinter-resisting door. Price £14 15s.

overlap " Densyl " plastic sealing material being used to make the closure gas-tight. The heavier door, 5 ft. 6 in. by 2 ft., is priced at £13 5s. See Figs. 85, 86 and 87.

Messrs. the Fireproof Shutter and Door Co. of Croydon have a range of eight types of "Raidoors." A useful type "R," 2 ft. 2 in. by 6 ft.—the size of a railway carriage door—constructed of two $\frac{1}{4}$ in. solid steel plates with impact absorbing material between, angle frame and adjustable gas-insulation, hatch and double-acting bolts engaging at three points, costs £10 delivered.

Heavier laminated doors embodying durasteel are also supplied by this firm.

Messrs. R. Costain Ltd. supply doors as below.

Gas-tight Steel Doors

These are made of $\frac{1}{8}$ in. plate, with two hinges and two refrigerator type fasteners. The frame is made of $2\frac{1}{2}$ in. by $2\frac{1}{2}$ in. by $\frac{5}{16}$ in. angles, with six lugs welded on for building into walls.

The door is provided with a spy-hole glazed in splinter-proof glass. A rubber insertion is fitted into a groove in the door which bears against the angle iron frame to form a gas-tight joint.

These doors may be lifted completely off their hinges should the entrance be blocked by fallen masonry. Sizes and prices, delivered to the site :—

			£	s.	d.
2 ft. 3 in. by 6 ft. 3 in.	Weight	245 lb.	11	15	0
2 ft. 6 in. by 6 ft. 3 in.	,,	255 lb.	12	0	0
3 ft. 0 in. by 6 ft. 3 in.	,,	280 lb.	12	15	0

Splinter-proof Steel Doors

Made of $\frac{3}{4}$ in. mild steel or $\frac{5}{8}$ in. high tensile steel plate, with two hinges and two refrigerator type fasteners.

The frame is made of 3 in. by $\frac{5}{16}$ in. angles with six lugs welded on for building into walls.

In other respects, the door is similar to the gas-tight door. Sizes and prices, delivered to the site :—

			£	s.	d.
2 ft. 3 in. by 6 ft. 3 in.	Weight	545 lb. .	16	15	0
2 ft. 6 in. by 6 ft. 3 in.	,,	595 lb. .	17	0	0
3 ft. 0 in. by 6 ft. 3 in.	,,	710 lb. .	17	15	0

W. A. Hunwicks of Romford produces a door 5 ft. by 2 ft., constructed in ¼ in. thickness of special bullet-resisting steel. Weight 2 cwt. Price with frame £10 5*s.* net F.O.R. It is claimed that these doors are proof against the service rifle bullet fired from short range.

In this connection it may be of interest to note that in respect of penetration of bullets two half thicknesses of a material with air space between are together more effective than one thickness of the same material, especially when the outer sheet is spring-mounted on the inner.

High-resistance steel doors, specially designed for resistance against blast are supplied by Messrs. Universal Steel Doors Ltd., West Bromwich. They are constructed of ½ in. face plate and ¼ in. back plate with 8 in. cavity filled with gravel.

Swing doors having exceptionally high resistance and made to Air Ministry Specification—½ in. M.S. external plate and ¼ in. M.S. plate on inside with 10 in. of shingle between—cost approximately £2 10*s.* per sq. ft. fixed ; swing steel shutters of large dimensions and 1½ in. thick about £1 17*s.* per sq. ft. ; and large doors ¾ in. plated about £1 12*s.* 6*d.* per sq. ft. complete.

The Carrier Engineering type of door is shown in Fig. 88.

A door which complies completely with the full requirements set out on pp. 228 and 229 is illustrated in Fig. 89.

It is recommended that this door be installed so that the bottom of the door is 2 ft. from the floor of the shelter, and if the 2 ft. 6 in. size be adopted the inspection eye-piece will be at a convenient height. The transparent material used for the inspection port is a special fire-proof plastic which is stronger than glass and more transparent. Its principal physical properties are as follows :

Tensile strength at 20° C.	3·2–3·9 tons/sq. in.	
Impact strength at 20° C.	3·2–4·2 kg. cm.	On specimen in accordance with B.S.S. 488.
,, ,, 40° C. . . . . (Izod, cut notch)	4·3 kg. cm.	
Ultimate fibre stress in bend at 20° C.	6·0–7·0 tons/sq. in.	
Shear strength at 20° C.	4·0–4·2 ,,	
Proportional limit in compression at 60° C.	1·8 ,,	
,, ,, ,, ,, 40° C	11·0 ,,	
Compressive strength at − 40° C.	14·5 ,,	
Brinell hardness	18–20	
Modulus of elasticity at 20° C.	200 tons/sq. in.	

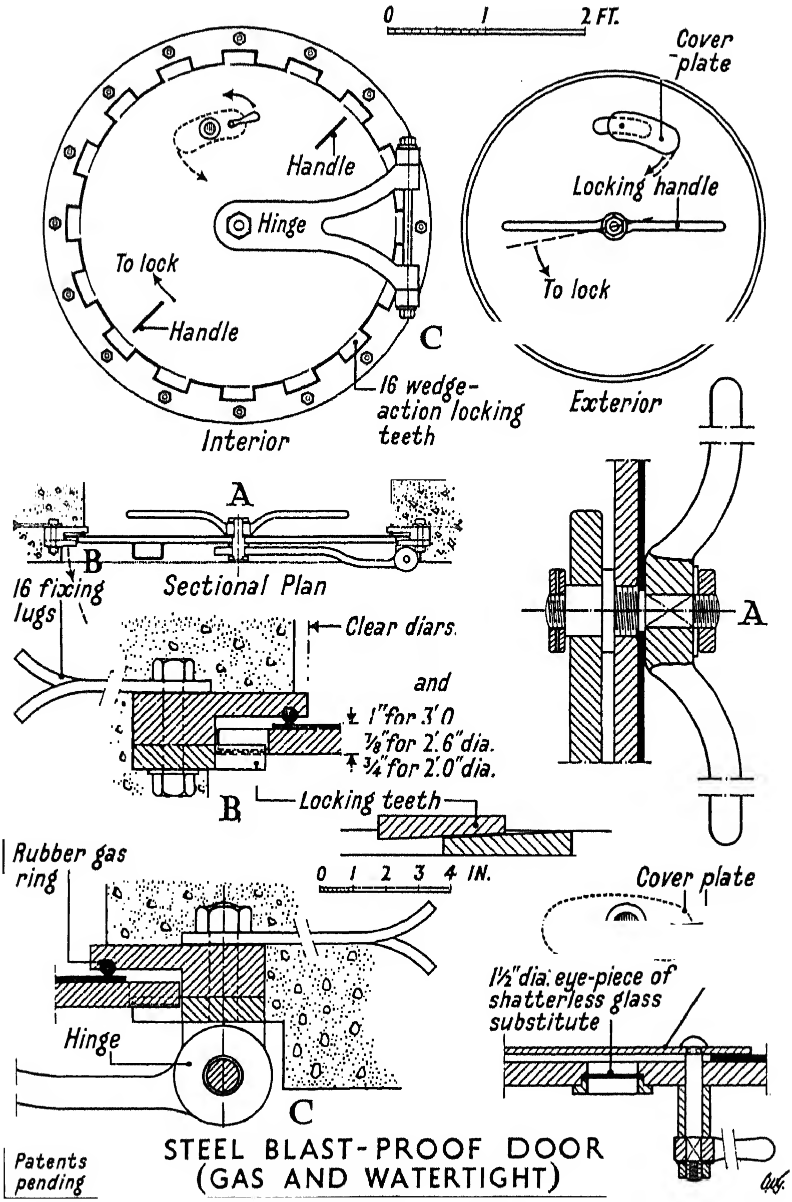

FIG. 89.—Special blast-proof, splinter-resisting and water- and gas-proof door of high efficiency.

The principal advantages of this type of door are :—

(*a*) It is gas-proof, water-proof, fire-proof and splinter-proof ; also blast-proof to the high degree specified on p. 228.

(*b*) It is hung on special hinges permitting the sixteen peripheral locking wedges to force the door on to the renewable rubber seating easily by the turn of the handle on either side of the door.

(*c*) The door opens inwards, thus avoiding inadvertent wedging by *débris* external to the shelter.

(*d*) The operating mechanism is inside, safe from damage by splinters.

(*e*) The wedging mechanism is positive, and is not subject to loosening by vibration. On the other hand, a child can operate it.

(*f*) Suitable equally for principal entrance or emergency exit.

Three sizes of this special door are available at the prices given below :—

3 ft. 0 in. diameter,	1 in. thick	£35 each (with frame).		
2 ft. 6 in. ,,	⅞ in. ,,	£30	,,	,,
2 ft. 0 in. ,,	¾ in. ,,	£25	,,	,,

obtainable from Messrs. Universal Floors Ltd., 91 Gower Street.

Spare rubber seating	5/–
Spare eye-piece	2/–

Emergency Exits

The horizontal emergency exit and gas seal illustrated in Fig. 90 has the advantage of serving a recognised peace time application as a cellar grating or light shaft fitting and may be used as such with full normal efficiency, while providing a completely effective unit for passive defence.

The frame has the form of a stepped gutter of rectangular outline in plan. It carries in the upper recess the grating which is constructed of a box girder provided with a continuous welded and riveted grill forming a strong light component.

The sealing bell is a separate shallow tray which, under normal circumstances, is stored in the light shaft but may be placed in position in the lower portion of the frame beneath the grating as shown in the figure.

The sealing bell is provided with an internal hook for attach-

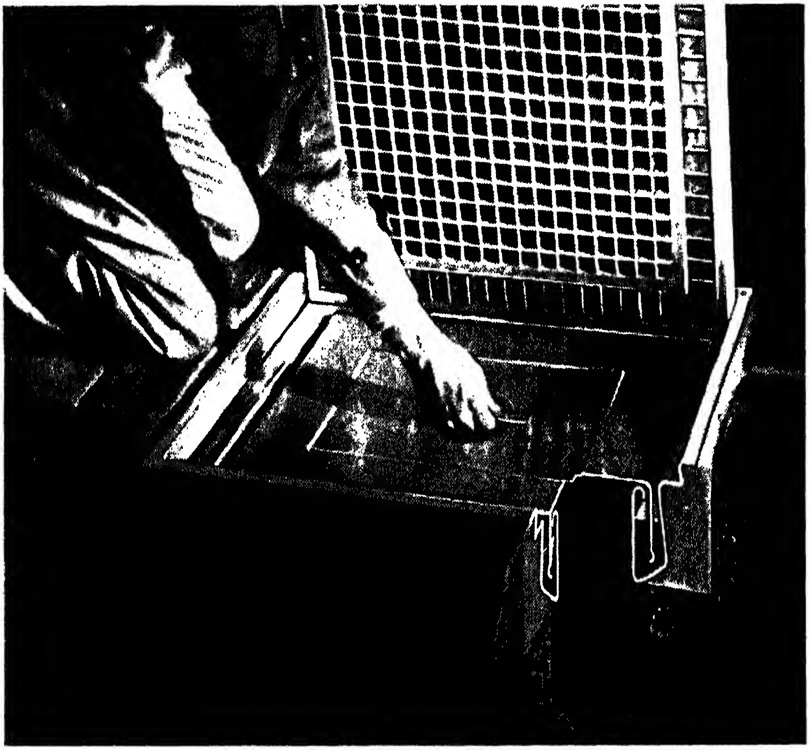

Fig. 90.—Horizontal emergency exit and gas seal.

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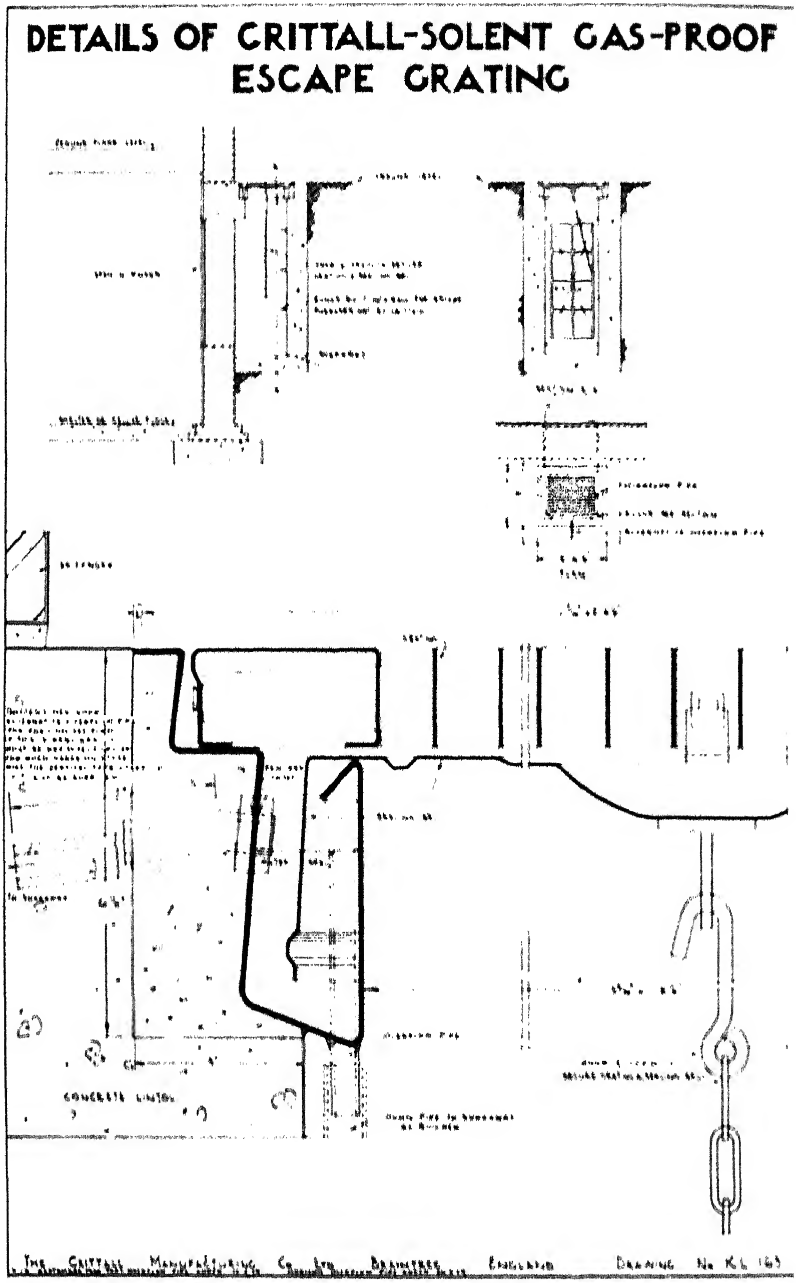


FIG. 91.—Details of grating shown in Fig. 90.

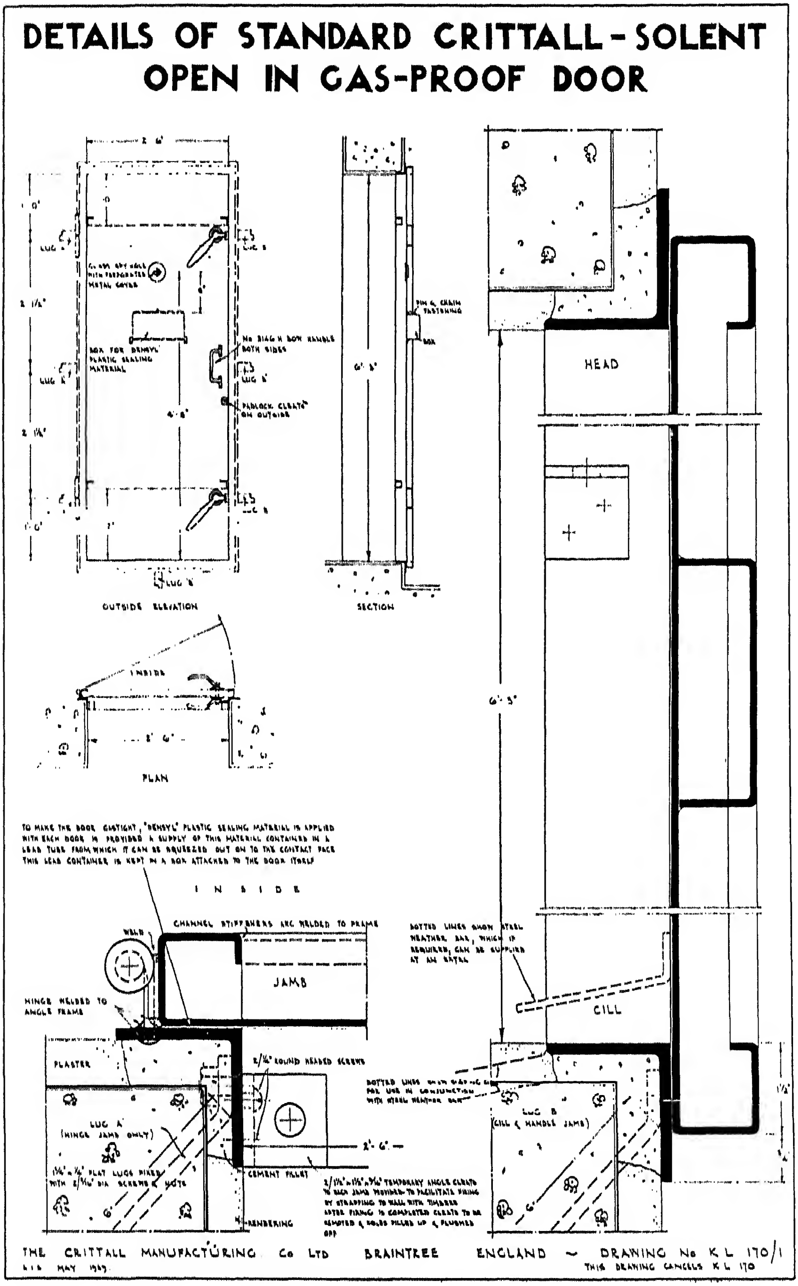


Fig. 93.—Crittall open-in gas-proof door.

DETAILS OF STANDARD CRITTALL-SOLENT GAS-PROOF SPLINTER RESISTING DOOR

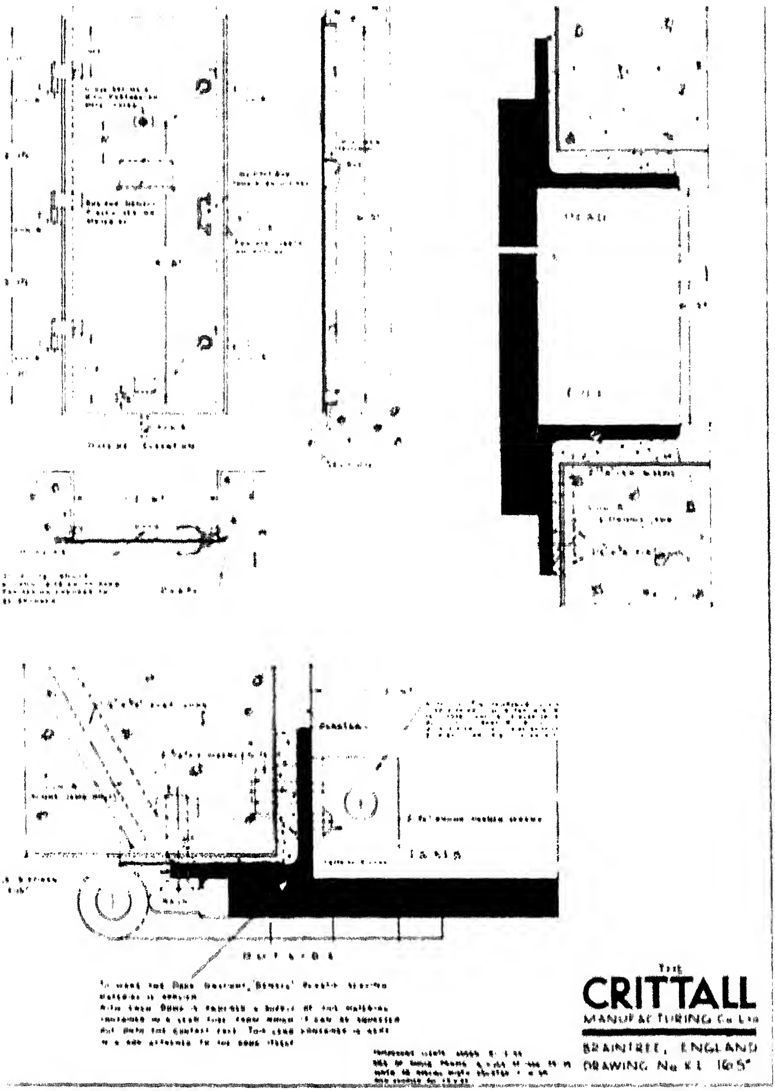


FIG. 94.—Crittall splinter-resisting door.

[To face p. 239.

ment of a chain and an external projection which interlocks with the grating. This is to enable the sealing bell and grating to be locked in position from inside in an emergency and thus prevent unauthorised entry.

In emergency the grating is raised, the sealing bell is put into position in the gutter and water is thrown over it to establish the seal.

It is clear that even major settlement and distortion of the buildings and surroundings will not upset the gas seal.

The grating has been tested to carry a load of 4 tons without injury and this is far in excess of the actual loading which can arise other than by a direct hit.

After the emergency the occupants may leave the shelter through the door leading to the building but if this is blocked they can escape through the emergency exit into the street.

Supplied by the Crittall Engineering Co.

Asphalte

Asphalte mastics are water-proofing and finishing products, and not structural materials called upon to resist the forces of penetration and explosion of bombs. On the other hand, asphaltes may be used in the water-proofing of shelters, as protection against the incendiary bomb and as a covering now immune from the action of gas.

Current building practice, so far as asphalte is concerned, need not be modified, except in the case of special buildings where anti-gas measures have specially to be considered.

A grade of asphalte suitable for use in such circumstances has been evolved, and is now available from all members of the Natural Asphalte Mine-owners and Manufacturers Council, Terminal House, S.W.1. For ordinary roof covering the usual grades normally employed are satisfactory.

Asphalte mastics comply with the B.S.I. Specification, No. 476, 1932, for non-inflammability, and are approved under the rules of the Fire Offices Committee for fire-resisting construction.

It has also been proved that asphalte has a remarkably high resistance to attack by incendiary bombs, and a deliberate attempt to destroy a boarded asphalted roof by igniting the asphalte with incendiary bombs failed completely.

CHAPTER VII

THE STRENGTHENING OF EXISTING BUILDINGS

Note. Data reproduced in this section has been taken, by permission of the Council of the Air Raid Protection Institute, largely from a paper on the subject given by the author at a General Meeting of the Institute on May 9th, 1939.

Introduction

In the consideration of structural passive defence, the author has found it convenient to classify the hazards and the degrees of protection as below :—

TABLE LXVIII

Approx. cost of protection per person accommodated at "Normal" capacity.	Hazard.	Category No. 1	2	3	4	5	6	7	8
(a)	Machine gun								
(b)	Gas spray	Refuges in buildings							
(c) 10/- to £1	Gas bomb		Refuges in buildings	Covered trenches in open					
(d) £1 to 1/10/-	Fire bomb				Covered trenches in open				
(e) 10/- to £1	Splinters & fragments					Covered trenches in open			
(f) £1 to 1/10/-	Blast from H.E.						Strongholds A		
(g) £2 to £3	Demolition of buildings							Strongholds B	
(h) £10 to £15	Direct hit ¼ ton H.E. Bomb								Strong-holds C
(j) £15 to £20	" " ½ " " "								
(k) £30 to £50	" " 1 " " "								

Whilst protection up to and including Class 5 can usually be provided most economically in covered trenches in the open, in many cases protection up to Classes 5 and 6 is required in city buildings which have to remain in occupation during an aerial bombardment.

It is the author's present purpose to draw attention to some of the problems involved in strengthening structures to form protected accommodation and to suggest practical methods of approach to the subject.

The investigation of the strength of existing buildings and the design of bomb-proof shelters is undoubtedly the responsibility of the structural engineer, who, working in collaboration with the architect can best advise upon the measures to be taken in safety in construction and the adaptation of buildings.

In strengthening works, careful calculations regarding the elastic deflection of the existing structure will need to be made so as to ascertain by how much the old work will have to be wedged or jacked up to ensure that the new work takes its fair proportion of the load *before the existing structure is overstressed.* Works of this nature are more difficult to design and execute than are new works, and must therefore be entrusted to competent engineers.

Types of Buildings

It is a comforting fact that a really well-designed frame building of modern construction is difficult completely to destroy by aerial bombardment.

On the other hand, unframed buildings with load-bearing walls, unless made unusually strong and massive, are very vulnerable to damage by blast and collapse, causing the superstructure to fall on the occupants.

The reader is referred to remarks under this heading on pp. 208–211.

Summarising the position, we see that the types of building fall in the approximate order of safety given in Table LXIX.

The reader will appreciate that the above classification can only be taken as a general guide, since special features, like brick or concrete vaulted basements, continuous, reinforced foundations, etc., have to be taken into account.

TABLE LXIX

Type.	Advantages.	Disadvantages.
A. Monolithic reinforced concrete framed building with solid concrete floors and "safety valve" wall panels.	High resistance against incendiary bomb, fire, earth tremor, difficult to bring down even with direct hit.	None if all heavy loading is on lower floors.
B. Welded steel frame building with solid concrete floors and "safety valve" wall panels.	Do. do.	Do. do.
C. Ordinary steel-framed building of fire resisting construction with safety valve wall panels.	Fire resistance and safety of framework even under direct hit.	Less resistance to earth tremor due to reduced resistance at joints compared with A or B.
D. Framed fireproof floor construction on load-bearing walls.	Fire resistance and protection against splinters.	Danger of collapse under blast and earth tremor.
E. Light timber-framed building well braced and with fireproof floors.	Resistance of frame to blast and earth tremor.	Fire risk damage by splinters and blast.
F. Ordinary cottage construction.	None.	Vulnerable to all hazards except in strengthened basement.

STRENGTHENING AGAINST THE PENETRATION OF THE INCENDIARY BOMB

In multi-storey buildings the stair well, lift shaft and such circulating spaces are, as a rule, the most fire-resistant and most structurally sound portions of the building. They can at slight extra cost be provided with special, reinforced concrete, light bomb-proof or bomb-deflecting roofs, generally as shown in Fig. 13. Two alternative roofs are indicated, and the designer must select that which is most suitable to the case under consideration.

Such a construction involves only the thickening of the concrete roof of the building and the strengthening of the columns to carry the additional load. The staircase should be so placed that it can be quickly reached in the case of alarm

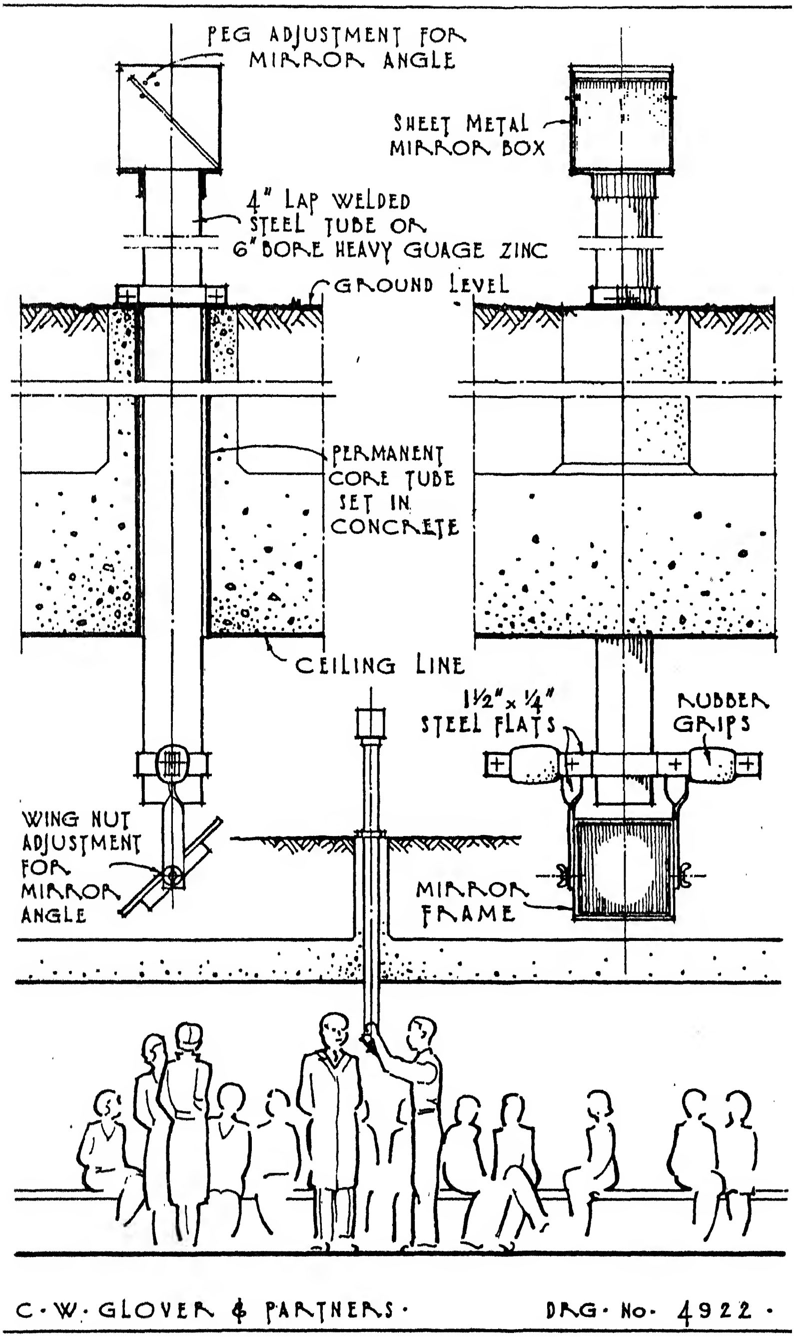


Fig. 94a.—Details of look-out periscope for air raid shelters.

and be sufficiently protected to provide a safe communication for the occupants of the building to a shelter at the base of it.

In small buildings protection against the kilo incendiary bomb can be effected by the adoption of one or other of the methods shown in Fig. 16, the roof timbers being protected with fire-resisting paint.

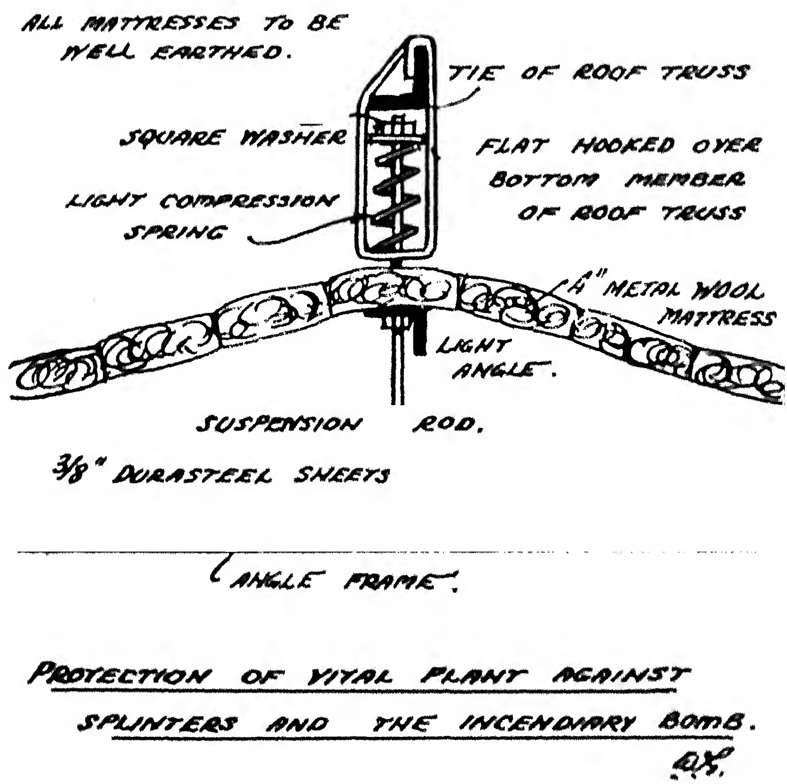


FIG. 95.

Fig. 116 shows the use of a 4-in. incendiary bomb slab at loft-floor level and incidentally indicates a form of basement shelter in reinforced concrete suitable for a semi-detached house.

Suitable reinforcement is in the form of a grid of $\frac{3}{8}$-in. diameter M.S. bars laid in both directions at 9 in. centre to centre forming a 9-in. square mesh on both sides of the wall,

all angles being well tied together with fillet and trimmer bars.

The cost of incorporating such a shelter in a new house would be approximately £145 extra to that of a similar house without a basement.

Fig. 159 shows yet another method of dealing with the incendiary bomb and will be self-explanatory. The illustration

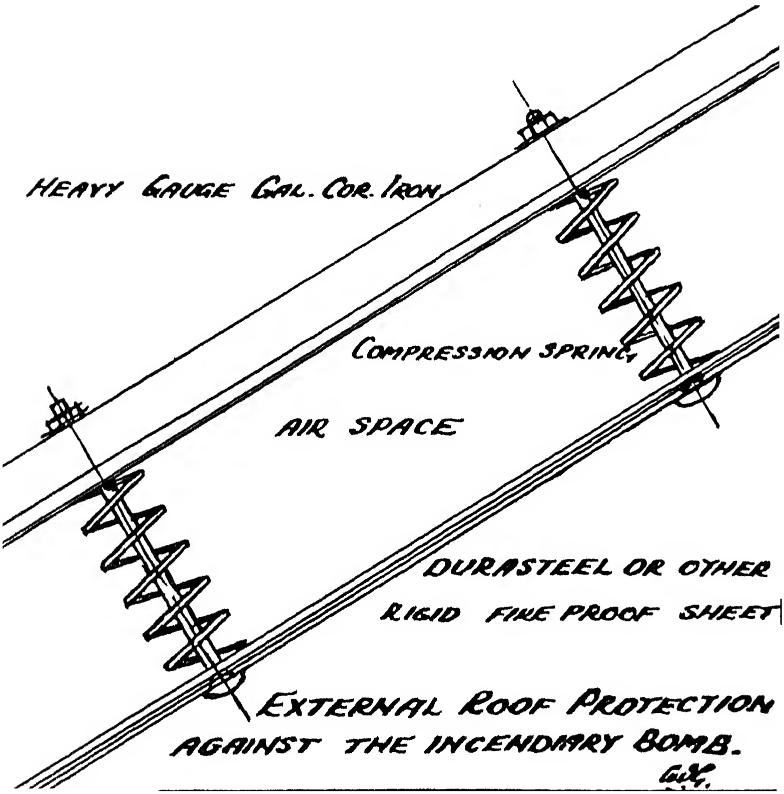


FIG. 96.

also shows how a room can be strengthened to provide Class 5 protection, the work remaining inconspicuous.

The approximate cost for a room 12 ft. by 12 ft. by 8 ft. 6 in. high would be £100 if an existing building were altered, but would only be £25 additional to the cost of a building constructed with the protective works included in the specification.

Protection against the penetration of splinters, A.A. shell

fragments and light incendiary bombs can be afforded by the use of metal wool mattresses on spring suspension supporting fire-resisting plates generally as indicated in Figs. 95 and 96.

Methods such as these will be found suitable where large roof areas have to be dealt with and the structural strength required for the support of concrete slabs on layers of sand or foamed slag is inadequate.

The impact-resisting, steel roof-cover sheets can be designed for complete protection against the small incendiary bomb which has a sectional density of approximately 0·5 lb. per sq. in. and a terminal velocity not exceeding 400 ft. per second.

Heavy incendiary bombs and small high-explosive bombs have a sectional density approaching 2 lb. per sq. in. and a terminal velocity which can be calculated from the formula

$$V = Vo\sqrt{\frac{Q}{a}}$$

Where Vo is the terminal velocity corresponding to unit values for Q and a and would normally be 600 ft. per second. Q is the sectional density and a is a coefficient which depends on the velocity and the form of the bomb. a is approximately unity for velocities up to about 800 ft. per second, increasing to a maximum of 4 at 1,500 ft. per second.

Thus, in this case

$$V = 600\sqrt{2}$$
$$= \underline{846 \text{ ft. per second.}}$$

Assuming a striking velocity of 850 ft. per second, it is thus possible to design a spring-supported impact sheet to absorb the energy of impact of incendiary bombs having no appreciable disruptive charge.

If the bomb weighs 10 kilos and the deflection on the springs be 1 ft., the force to be resisted may be estimated from the formula

$$P = \frac{mV^2}{2gd}$$
$$= \frac{22 \times 850^2}{2 \times 32 \times 1} = \underline{235{,}200 \text{ lb.}}$$

A 1 kilo incendiary bomb arriving at 400 ft. per second would exert an impact force of 16,500 lb. in deflecting the springs 4 in.

PROTECTION AGAINST THE EFFECTS OF HIGH EXPLOSIVE BOMBS

The strengthening of buildings against the multifarious effects of bombardment with high explosive involves a prohibitively great expenditure if a high degree of protection is attempted.

It will normally be sufficient to provide Class 5 protection in that section of the building required for occupation during a bombardment.

Let us then examine the "loading" to which such protected accommodation would be likely to be subjected.

Hazard a

Machine-gun. A remote contingency, but it is evident that protection against splinter and fragments provides ample defence against the penetration of machine-gun bullets.

Hazard b

Gas Spray. The usual gas-proofing measures with provision for decontamination at entrances meet this contingency.

Hazard c

Gas Bomb. Protection against splinters and demolition of superstructure usually affords ample protection against penetration of gas bombs.

Hazard d

Fire Bomb. This has already been dealt with.

Hazard e

Splinters and Fragments. The penetration effect of splinters is greater than that of bombs weight for weight, owing to the greater velocity of the former—some 5,000 ft. per second compared with a bomb arrival velocity not exceeding 1,200 ft. per second. Further, the sectional density of A.A. shell fragments is vastly greater than that of bombs. To meet this

hazard, the author therefore ensures that for any possible angle of impact the aggregate shelter wall or roof thicknesses do not fall below the minima given in the following table :—

TABLE LXX

	in.
M.S. steel plate	$1\frac{1}{2}$
Steel armour plate	1
Reinforced concrete	12
Plain concrete	16
Good, solid brickwork	$13\frac{1}{2}$
Sand or earth	30

Hazard f

Blast. The effect of blast on a shelter constructed within a building will depend principally upon the position of the shelter and upon the natural period of vibration of the building or structural elements surrounding the shelter. As the phase of positive pressure is followed by a phase of negative pressure in an interval of about two-thousandths of a second to about a tenth of a second (according to the amount of the charge), a building of high natural frequency will normally suffer most by blast. The effects of blast are being investigated by the Institution of Civil Engineers, but there is no doubt that there is considerable screening in a basement shelter and the effects of blast on a building can be minimised if wall panels are of the light, safety-valve type.

Hazard g

Demolition of Superstructure. This may conveniently be divided into two sections :—

1. Vertical loads.
2. Horizontal loads due to :—
   (*a*) Blast.
   (*b*) Earth tremor.

1. *Vertical Loads due to Demolition Effects.* It is obvious that the roof of a shelter must be strong enough to withstand safely the impact due to the collapse of a superstructure and its contents, which may fall on the shelter during a bombardment.

Floor loads allowed for in design or as called for by building regulations are seldom reached in practice, but the actual loading obtaining in any building under consideration must be calculated when designing a basement or ground-floor shelter.

The Swiss authorities recommend as follows :—

" To withstand the indirect demolition effects of H.E. bombs, *i.e.*, the collapse of high buildings, protective ceilings must be designed to carry *the entire weight, including such larger useful loads as may be found in storehouses, factories, etc.*

" For purely residential buildings, under normal conditions, the distributed loads are given in Table LXIII.

" The appropriate dimensions for the protective ceilings, taking into account the effect of *débris* when a house with reinforced concrete floors collapses, are given approximately in Table LXXI, the higher values being applicable to a joist with ends freely supported and the smaller to those with ends rigidly fixed.

Table LXXI

Ceiling Thickness Required to Withstand Demolition Effects

Span.	Thickness of Ceiling in Inches.			
	Four Upper Floors and Roof.	Three Upper Floors and Roof.	Two Upper Floors and Roof.	One Upper Floor and Roof.
	Concentrated Load, 20 Tons.		Concentrated Load, 15 Tons.	
13′ × 13′, supported on four sides	9″–10″	9″	8½″	8½″
16′ × 13′, supported on four sides	11″–12″	9″–11″	8½″–9½″	8½″
Long slab, 13′ span	12″–15½	11″–14″	10″–13″	8½″–11″
Long slab, 16′ span	13″–19″	13″–17½″	12½″–16″	10½″–13½″

" A rigid generalisation from the values given may yield disastrous results. Calculations for ceilings proof against collapse must be made by an engineer with due regard to the loads they may have to bear and the static characteristics of the building."

The German regulations are considered adequate by the British Home Office, the design loads being as in Table LXIV. These loads are over and above the floor loads for which the structure is normally designed.

A few calculations will show that the lighter loadings given in Table LXIV encroach upon the usual factors of safety at the

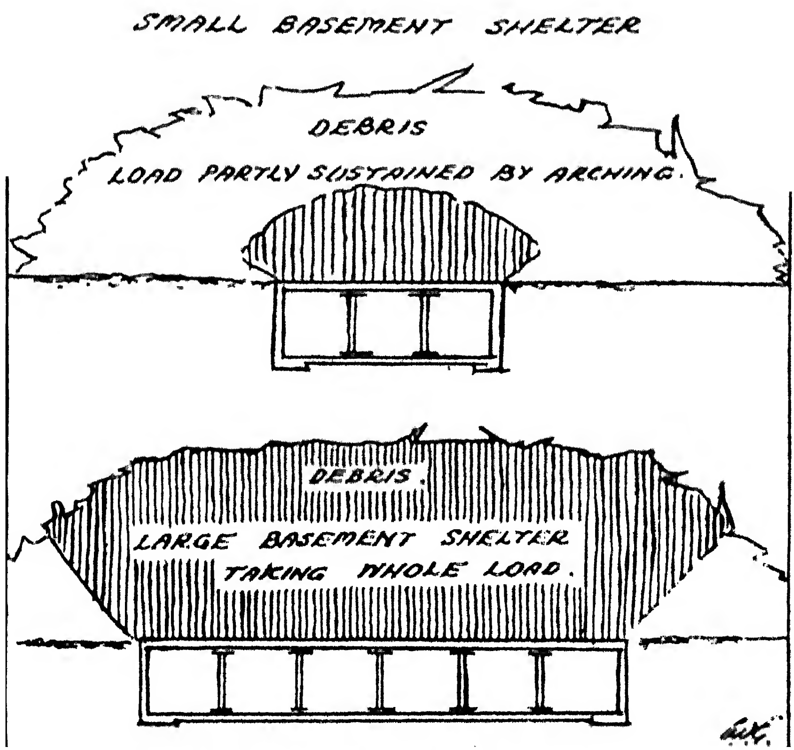


FIG. 97.—Showing "arching" effect of *débris* load on small shelters.

moment of impact of the *débris* on the shelter roof, but that in the case of small shelters the arching effect of the *débris* may relieve the shelter roof of some of the load.

Fig. 97 shows this effect diagrammatically, the cross hatched portions of the load being that not supported by any sustaining or arching effect in the load itself.

The author is therefore definitely of the opinion that the

higher loadings should be allowed for in all basement strengthening work, especially when the whole of the basement of city office buildings is required as a shelter.

The point loads given in Table LXXI are intended for calculation of the punching shear only.

Horizontal Loading

(*a*) *Blast.* As already stated, for basement shelters the horizontal loading due to blast is as yet an undetermined

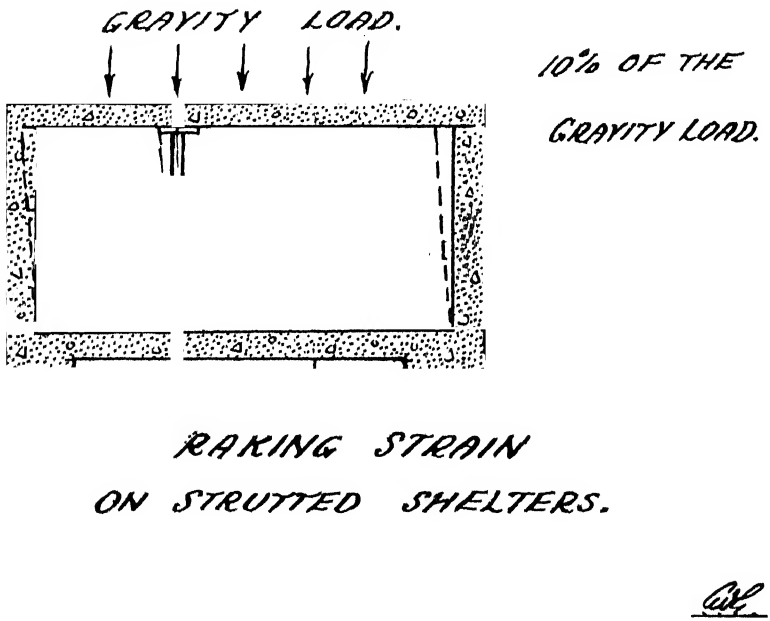


FIG. 98.—Raking strain on buried shelters.

factor, but, in the opinion of the author, the allowance for earth tremor should prove adequate to cover this contingency.

The outside walls of basement shelters should, of course, be capable of taking all the external forces acting upon them,

especially the horizontal thrust due to earth pressures or blast, when the stabilising effect of superincumbent loads might have been removed by the collapse of the building.

Earth tremors due to nearby explosions of bombs also have to be allowed for, and to this end, if the wall is a long one, buttresses at frequent intervals should be constructed and the roof and ground concrete reinforced continuously with the side walls.

Earth tremors due to bombs produce seismic effects similar to those of earthquakes and methods adopted in anti-seismic

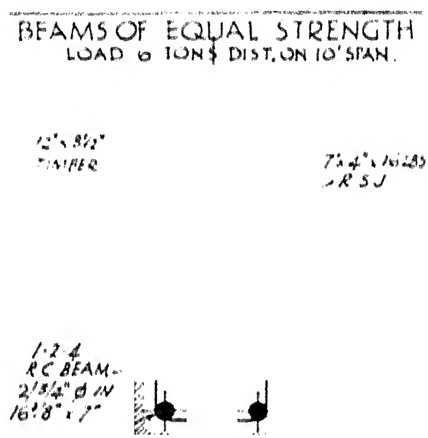


FIG. 99.—Sections of beams of equal strength.

construction are likely to be effective. See also remarks on p. 49.

Using the 10 per cent. gravity load as the horizontal force applied at the roof of a basement shelter, the strengthening required to prevent deformation or raking strain, as indicated in Fig. 98, can be calculated.

Cross bracing, buttresses, cross walls, or the insertion of rigid frames may be adopted, but seldom in existing buildings in this country will adequate strength be found in basements without supplementary reinforcement.

Materials

There is no doubt that in the adoption of strengthening measures, materials that may be readily available would have

to be used. Timber, steel and reinforced concrete are the principal materials suitable, and in this connection, Fig. 99, showing the sections of beams of equal strength designed in the three materials to the usual stresses, may restore some waning confidence in good sound timber.

Timber. Working stresses for timber are given in Table LXXII.

TABLE LXXII

Timber.	Working Stress in lb. per sq. in.					Young's Modulus E.
	Compression.		Tension.	Shear along Grain.	Bending Shear.	
	Side Grain.	End Grain.				
Redwood .	250	1,100	Same as	120	100	1,200,000
Pitch pine .	300	1,200	for end	180	120	1,500,000
Spruce . .	225	900	compres-	100	80	1,200,000
Douglas fir .	310	1,200	sion	170	110	1,510,000
Oak . .	450	1,200		200	130	1,200,000

For timber struts the least lateral dimension should not be less than one-fifteenth of the length and for posts with square end bearing the maximum allowable compression stress should be 1,000 lb. per sq. in., reduced in accordance with the following formula :—

$$\text{Safe unit stress} = 1{,}000\left(1 - \frac{h}{80d}\right)$$

Where h is the unsupported length in inches and d is the least dimension of the cross section in inches.

For ordinary conditions this gives a safe compressive stress of about 700–800 lb. per sq. in.—more than twice that allowable in compression on side grain.

The sizes of posts are therefore limited by the compression of the timbers they carry, but when hardwood caps or wedges are used, the allowable stress across the grain may be increased 50 per cent.

It must be remembered that the drying shrinkage of timber across grain is considerable, and timber strutting to basements must be kept wedged up to compensate for this effect.

Fig. 100 shows a suitable arrangement and Table LXXIII gives the sizes of the various scantlings for demolition loads of from 200 to 1,000 lb. per sq. ft.

A convenient span centre to centre of posts and centre to centre of frames is 8 ft. and the tables have been drawn up to comply with this arrangement.

The approximate cost per square foot of floor supported is also given in Table LXXIII for the strutting alone.

It is desirable to use continuous plates at floor level to distribute the load on the basement floor, thus avoiding the cost of digging and the possible disturbance of existing foundations.

The floor could be made level with the tops of the plates *d* by the use of dry sand or foamed slag filling and this will be found of considerable advantage in the minimisation of concussion, which would otherwise be transmitted by earth tremors from nearby bursts to the persons standing on the floor.

When the whole basement is strutted from side to side, the resistance of the earth behind the retaining walls assists in taking the raking strains.

The safe horizontal force in pounds at the top of the wall towards the external earth would be of the order of fifty times the square of the height of the basement in feet, per foot run of wall, assuming there were no surcharge, the earth weighs 100 lb. per cub. ft. and has an angle of repose of not less than 30 degrees.

On a spacing of 8 ft. and a shelter height of 10 ft., the thrust thus provided works out to approximately 40,000 lb. suitable for the stabilisation of the gravity load on ten bays loaded to 500 lb. per sq. ft.

The braces E are therefore designed for part of the horizontal loads only.

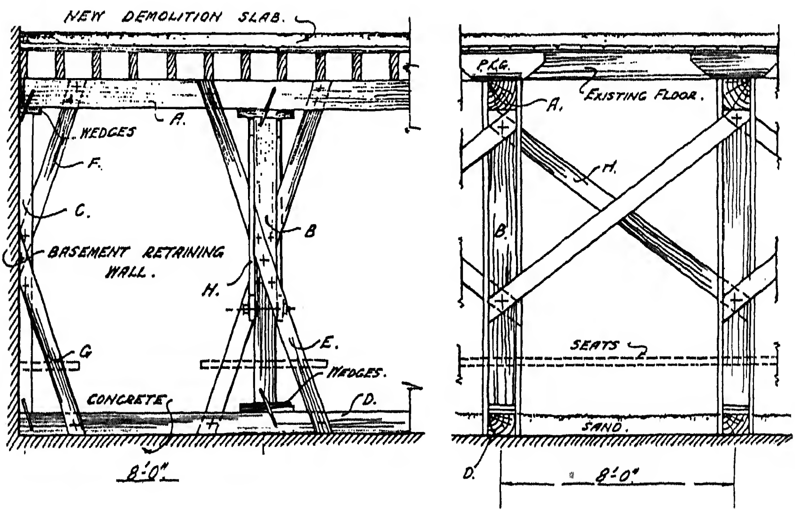
The strength of framed timber-work is often limited by the strength of the joints and the use of timber connectors and bolt holes of the *same* diameters as the bolts greatly increases the efficiency of the joints.

As most ground floors cannot be relied upon to take much more than their original design load, it will be found convenient to provide an additional slab to span between the frames of

strutting placed at 8 ft. centres generally, as shown in Fig. 100.

The existing floor is used as permanent shuttering for the "demolition" slab formed in reinforced concrete *in situ* over it. When the existing floor is of timber, its resistance to punching shear is negligible, and if, therefore, this is taken entirely by the new slab the minimum nett depth required is 6 in.

Table LXXIV shows the thicknesses and reinforcement required in demolition slabs continuous over one support on



— A. R. P. — TIMBER STRUTTING FOR BASEMENTS —

FIG. 100.

a span of 8 ft., worked out at 25 per cent. on the code stresses for 1 : 2 : 4 P.C. concrete reinforced with mild steel. Results are tabulated for the distributed loads or the "Point" loads carried on 9 sq. ft. of slab in the centre of the span.

Using a grid of steel of equal section each way laid diagonally across the span, the maximum resistance to punching shear is developed and difficulties of proportions of long slabs are overcome developing "square slab" effects to a certain degree irrespective of the plan shape of the shelter.

In all the design tables the dead loads have been allowed for and the tabulated demolition loads are nett.

In Air Raid Precautions Memorandum No. 10 the official loading above referred to is confirmed, but the permissible stresses in additional supporting work are restricted to those laid down in the various current building regulations.

The superimposed loads given in this official memorandum [118] go up to 400 lb. per sq. ft., and are considered a reasonable provision for the collapse of buildings of normal construction. If the buildings have abnormal features, such as heavy colonnades, pediments, cornices, etc., which would be likely to produce abnormal *debris* loads, *higher values should be taken according to the judgment of competent architects and engineers.*

TABLE LXXIV

REINFORCED CONCRETE DEMOLITION SLABS

(*End Span Condition*)

Span 8 ft. 0 in.

For 1 : 2 : 4 Ordinary P.C. Concrete with Code Stresses both in Steel and Concrete increased by 25 per cent.

Load.	Bending Moment in lbs./in.	Depth.	Steel.	Price per sq. ft. of Slab.
20 tons "point"	244,000	12½″	¾″ at 5″	32*d.*
15 tons ,, ...	184,000	11″	¾″ at 5½″	28*d.*
200 lb. distributed load per sq. ft..	26,300	4½″	½″ at 6″	9*d.*
300 ,, ,, ,, ,, .	34,000	5″	½″ at 5½″	10*d.*
400 ,, ,, ,, ,, .	42,000	5½″	½″ at 5″	11*d.*
500 ,, ,, ,, ,, .	49,600	6″	9/16″ at 6″	11½*d.*
600 ,, ,, ,, ,, .	57,400	6½″	9/16″ at 5½″	12*d.*
700 ,, ,, ,, ,, .	65,000	7″	⅝″ at 6″	13½*d.*
800 ,, ,, ,, ,, .	72,000	7″	⅝″ at 6″	13½*d.*
900 ,, ,, ,, ,, .	80,500	7½″	⅝″ at 5½″	15*d.*
1,000 ,, ,, ,, ,, .	88,400	8″	⅝″ at 5½″	15½*d.*

Minimum depth for punching shear for 20 tons load on 10″ diameter circle = 6″.

For the convenience of the designer, Tables LXXIV—LXXIX, based upon those in Memorandum 10, have been extended to higher loadings.

It has been assumed that most systems of strengthening in timber will involve the use of close sheeting under the existing floor, supported by beams with braced struts under and supported on sole pieces, as shown in Fig. 101.

TABLE LXXIII

SHOWING SCANTLINGS REQUIRED IN TIMBER STRUTTING FOR BASEMENT NOT EXCEEDING 12 FT. HIGH (FIG. 100)

No.	Demolition Load.	Posts 8 ft. each Way.								Net Width of Frame.	Price per sq. ft. of Floor.
		A	B	C	D	E	F	G	H		
1	15 tons point .	9"×16"	9"×9"	5"×9"	12"×9"	6"×1½"	6"×1½"	6"×1½"	7"×2"	9"	22*d*.
2	20 ,, ,, .	10"×17"	10"×10"	5"×10"	10"×13"	6"×1½"	6"×1½"	6"×1½"	7"×2"	10"	27*d*.
3	200 lb. per sq. ft .	9"×10"	9"×6"	3"×9"	7"×9"	6"×1½"	6"×1½"	6"×1½"	7"×2"	9"	15*d*.
4	300 ,, ,, .	10"×11"	10"×7"	4"×10"	8"×10"	6"×1½"	6"×1½"	6"×1½"	7"×2"	10"	18*d*.
5	400 ,, ,, .	10"×12"	10"×8"	4"×10"	9"×10"	6"×1½"	6"×1½"	6"×1½"	7"×2"	10"	20*d*.
6	500 ,, ,, .	11"×12"	11"×9"	5"×11"	9"×11"	6"×1½"	6"×1½"	6"×1½"	7"×2"	11"	23*d*.
7	600 ,, ,, .	11"×13"	11"×10"	5"×11"	10"×11"	6"×2"	6"×2"	6"×2"	7"×2½"	11"	25*d*.
8	700 ,, ,, .	13"×13"	13"×9"	5"×13"	10"×13"	6"×2"	6"×2"	6"×2"	7"×2½"	13"	28*d*.
9	800 ,, ,, .	12"×14"	12"×12"	6"×12"	11"×12"	7"×2"	7"×2"	7"×2"	7"×3"	12"	31*d*.
10	900 ,, ,, .	13"×14"	13"×13"	6"×13"	11"×13"	7"×2"	7"×2"	7"×2"	7"×3"	13"	34*d*.
11	1,000 ,, ,, .	14"×14"	14"×12"	6"×14"	11"×14"	7"×2"	7"×2"	7"×2"	7"×3"	14"	35*d*.

TABLE LXXV

REINFORCED CONCRETE DEMOLITION SLABS

(End Span Condition)

Span 10 ft. 0 in.

For 1 : 2 : 4 Ordinary P.C. Concrete with Code Stresses both in Steel and Concrete increased by 25 per cent.

Load.	Bending Moment in lb./in.	Depth.	Steel.	Price per sq. ft. of Slab.
20 tons " point "	322,000	14½"	⅞" at 5½"	40d.
15 tons ,, ...	245,000	12½"	¾" at 5"	32d.
200 lb. distributed load per sq. ft. .	41,200	5½"	½" at 5"	10d.
300 ,, ,, ,, ,, .	53,200	6½"	9/16" at 5½"	11½d.
400 ,, ,, ,, ,, .	65,100	7"	9/16" at 5"	12½d.
500 ,, ,, ,, ,, .	77,200	7½"	⅝" at 6"	13½d.
600 ,, ,, ,, ,, .	89,200	8"	⅝" at 5½"	14½d.
700 ,, ,, ,, ,, .	101,000	8½"	⅝" at 5"	15½d.
800 ,, ,, ,, ,, .	111,300	9"	11/16" at 6"	16½d.
900 ,, ,, ,, ,, .	125,200	9½"	11/16" at 5½"	18½d.
1,000 ,, ,, ,, ,, .	137,000	10"	11/16" at 5"	19½d.

Minimum depth for punching shear for 20 tons load on 10" diameter circle 6"

The lower working stress is for unselected timber of the common carcassing class of European redwood, and the higher working stress of 1,200 lb. per sq. in. is suitable for timber equal to No. 1 merchantable (UKAY) grade of Douglas fir.

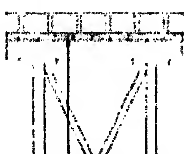


FIG. 101.

Slippers. Hardwood (oak, beech, birch, rock maple) slippers, 6 × 18 × 2 in., to distribute loads from struts to beams and sole pieces.
Sole Pieces. 6 × 2 in.
Cross Bracing. 3 × 2 in., cut to fit and joined at intersection.

TABLE LXXVI

9 × 3 IN. PLANK SHEETING, LAID FLAT AND CLOSELY SPACED

Debris load lb./sq. ft.	Clear span of sheeting = L (inches).		Size of beams (inches).	Clear span of beams = S (inches).		Sizes of struts (inches) for ceiling height above floor level = H.							
						7′ 6″		8′ 6″		9′ 6″		10′ 6″	
	f = 800 lb./sq. in.	f = 1200 lb./sq. in.		f = 800 lb./sq. in.	f = 1200 lb./sq. in.	f = 800 lb./sq. in.	f = 1200 lb./sq. in.	f = 800 lb./sq. in.	f = 1200 lb./sq. in.	f = 800 lb./sq. in.	f = 1200 lb./sq. in.	f = 800 lb./sq. in.	f = 1200 lb./sq. in.
200	83	—	6 × 6	42	47	6 × 3	6 × 3	6 × 4	6 × 4	6 × 4	6 × 4	6 × 4	6 × 4
	—	102	6 × 9	63	70	6 × 4	6 × 4	6 × 4	6 × 4	6 × 4	6 × 4	6 × 5	6 × 4
300	68	—	6 × 6	39	42	6 × 3	6 × 3	6 × 4	6 × 4	6 × 4	6 × 4	6 × 4	6 × 4
	—	83	6 × 9	58	64	6 × 4	6 × 4	6 × 4	6 × 4	6 × 5	6 × 4	6 × 5	6 × 4
400	59	—	6 × 6	35	39	6 × 4	6 × 4	6 × 4	6 × 4	6 × 4	6 × 4	6 × 4	6 × 4
	—	72	6 × 9	53	59	6 × 4	6 × 4	6 × 4	6 × 4	6 × 5	6 × 4	6 × 5	6 × 5
500	52	—	6 × 9	49	62	6 × 5	6 × 7	6 × 6	6 × 7	6 × 6	6 × 7	6 × 6	6 × 7
	—	64	6 × 9	45	56	6 × 6	6 × 7	6 × 6	6 × 7	6 × 6	6 × 7	6 × 6	6 × 7
600	48	—	6 × 9	47	58	6 × 6	6 × 7	6 × 6	6 × 7	6 × 6	6 × 7	6 × 6	6 × 7
	—	59	6 × 9	42	52	6 × 6	6 × 7	6 × 6	6 × 7	6 × 6	6 × 7	6 × 6	6 × 7

NOTE.—f = working fibre stress of timbei

TABLE LXXVII

9 × 4 IN. PLANK SHEETING. LAID FLAT AND CLOSELY SPACED

Debris load lb./sq. ft.	Clear span of sheeting = L (inches).		Size of beams (inches).	Clear span of beams = S (inches).		Sizes of struts (inches) for ceiling height above floor level = H.							
						7′ 6″		8′ 6″		9′ 6″		10′ 6″	
	f = lb./	1200 sq. in.		= 800 sq. in.	f = 12 lb./sq.	f = 8 lb./sq.	f = 12 lb./sq.	f = 8 lb./sq.	f = 1 lb./sq.	f lb.	= 1200 sq. in.	f = lb. sq.	100 in.
200	111	—	6 × 6	37	41	6 × 3	6 × 3	6 × 4	6 × 3	6 × 4	6 × 4	6 × 4	6 × 4
	—	135	6 × 9	56	61	6 × 4	6 × 4	6 × 4	6 × 4	6 × 5	6 × 4	6 × 5	6 × 4
300	90	—	6 × 6	34	37	6 × 4	6 × 3	6 × 4	6 × 4	6 × 4	6 × 4	6 × 5	6 × 4
	—	111	6 × 9	50	5[illegible]	6 × 4	6 × 4	6 × 5	6 × 4	6 × 5	6 × 4	6 × 5	6 × 5
400	78	—	6 × 6	31	35	6 × 4	6 × 3	6 × 4	6 × 4	6 × 5	6 × 4	6 × 5	6 × 5
	—	96	6 × 9	47	52	6 × 4	6 × 4	6 × 5	6 × 4	6 × 5	6 × 4	6 × 5	6 × 5
500	70	—	6 × 9	43	53	6 × 6	6 × 7	6 × 6	6 × 7	6 × 6	6 × 7	6 × 6	6 × 7
	—	86	6 × 9	38	4[illegible]	6 × 7	6 × 8	6 × 7	6 × [illegible]	6 × 7	6 × 8	6 × 7	6 × 8
600	64	—	6 × 9	41	50	6 × 6	6 × 7	6 × 6	6 × 7	6 × 6	6 × 7	6 × 6	6 × 7
	—	78	6 × 9	3[illegible]	4[illegible]	6 × 7	6 × 8	6 × 7	6 × 8	6 × 7	6 × 8	6 × 7	6 × 8

NOTE.—*f* = working fibre stress of timber.

TABLE LXXVIII

9 × 3 IN. PLANK SHEETING. LAID FLAT WITH 3 IN. CLEAR SPACE BETWEEN PLANKS

Debris load lb./sq. ft.	Clear span of sheeting = L (inches).		Size of beams (inches).	Clear span of beams = S (inches).		Sizes of struts (inches) for ceiling height above floor level = H.							
						7′ 6″		8′ 6″		9′ 6″		10′ 6″	
	f = 800 lb./sq. in.	f = 1200 lb./sq. in.		f = 800 lb./sq. in.	f = 1200 lb./sq. in.	f = 800 lb./sq. in.	f = 1200 lb./sq. in.	f = 800 lb./sq. in.	f = 1200 lb./sq. in.	f = 800 lb./sq. in.	f = 1200 lb./sq. in.	f = 800 lb./sq. in.	f = 1200 lb./sq. in.
200	72	—	6 × 6	45	52	6 × 3	6 × 3	6 × 4	6 × 4	6 × 4	6 × 4	6 × 4	6 × 4
	—	88	6 × 9	68	78	6 × 4	6 × 4	6 × 4	6 × 4	6 × 4	6 × 4	6 × 5	6 × 4
300	59	—	6 × 6	41	46	6 × 3	6 × 3	6 × 4	6 × 4	6 × 4	6 × 4	6 × 4	6 × 4
	—	72	6 × 9	61	69	6 × 4	6 × 4	6 × 4	6 × 4	6 × 4	6 × 4	6 × 5	6 × 4
400	51	—	6 × 6	39	43	6 × 4	6 × 3	6 × 4	6 × 4	6 × 4	6 × 4	6 × 4	6 × 4
	—	62	6 × 9	58	65	6 × 4	6 × 4	6 × 4	6 × 4	6 × 5	6 × 4	6 × 5	6 × 5
500	45	—	6 × 9	53	66	6 × 5	6 × 6	6 × 5	6 × 6	6 × 5	6 × 6	6 × 5	6 × 6
	—	55	6 × 9	48	60	6 × 6	6 × 7	6 × 6	6 × 7	6 × 6	6 × 7	6 × 6	6 × 7
600	42	—	6 × 9	50	62	6 × 6	6 × 7	6 × 6	6 × 7	6 × 6	6 × 7	6 × 6	6 × 7
	—	50	6 × 9	46	57	6 × 6	6 × 7	6 × 6	6 × 7	6 × 6	6 × 7	6 × 6	6 × 7

NOTE.—f = working fibre stress of timber.

TABLE LXXIX

9 × 4 IN. PLANK SHEETING. LAID FLAT, WITH 3 IN. CLEAR SPACE BETWEEN PLANKS

Debris load lb./sq. ft.	Clear span of sheeting = L (inches).		Size of beams (inches).	Clear span of beams = S (inches).		Sizes of struts (inches) for ceiling height above floor level = H.							
						7′ 6″		8′ 6″		9′ 6″		10′ 6″	
	f = 800 lb./sq. in.	f = 1200 lb./sq. in.		f = 800 lb./sq. in.	f = 1200 lb./sq. in.	f = 800 lb./sq. in.	f = 1200 lb./sq. in.	f = 800 lb./sq. in.	f = 1200 lb./sq. in.	f = 800 lb./sq. in.	f = 1200 lb./sq. in.	f = 800 lb./sq. in.	f = 1200 lb./sq. in.
200	96	—	6 × 6	38	48	6 × 3	6 × 4	6 × 4	6 × 4	6 × 4	6 × 4	6 × 4	6 × 4
	—	117	6 × 9	54	67	6 × 5	6 × 6	6 × 5	6 × 6	6 × 5	6 × 6	6 × 5	6 × 6
300	78	—	6 × 6	34	43	6 × 4	6 × 4	6 × 4	6 × 4	6 × 4	6 × 4	6 × 4	6 × 4
	—	96	6 × 9	48	60	6 × 6	6 × 7	6 × 6	6 × 7	6 × [illegible]	6 × 7	6 × 6	6 × 7
400	68	—	6 × 6	31	39	6 × 4	6 × 5	6 × 4	6 × 5	6 × 5	6 × 5	6 × 5	6 × 5
	—	83	6 × 9	44	55	6 × 6	6 × 7	6 × 6	6 × 7	6 × 6	6 × 7	6 × 6	6 × 7
500	60	—	6 × 9	46	57	6 × 6	6 × 7	6 × 6	6 × 7	6 × 6	6 × 7	6 × 6	6 × 7
	—	74	6 × 9	42	52	6 × 6	6 × 8	6 × 6	6 × 8	6 × 7	6 × 8	6 × 7	6 × 8
600	55	—	6 × 9	44	54	6 × 6	6 × 7	6 × 7	6 × 7	6 × 7	6 × 7	6 × 7	6 × 7
	—	67	6 × 9	40	49	6 × 7	6 × 8	6 × 7	6 × 8	6 × 7	6 × 8	6 × 7	6 × 8

NOTE.—f = working fibre stress of timber.

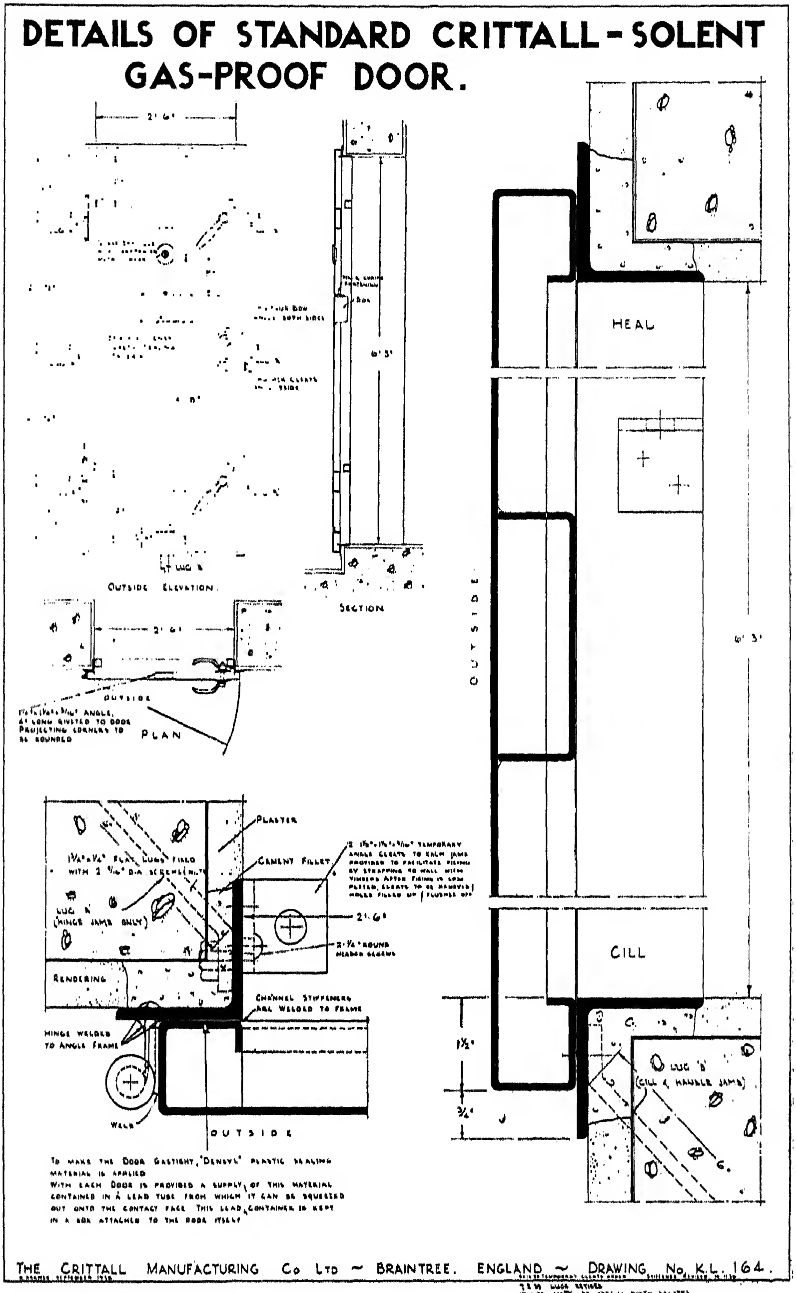


Fig. 92.—Crittall standard gas-proof door.

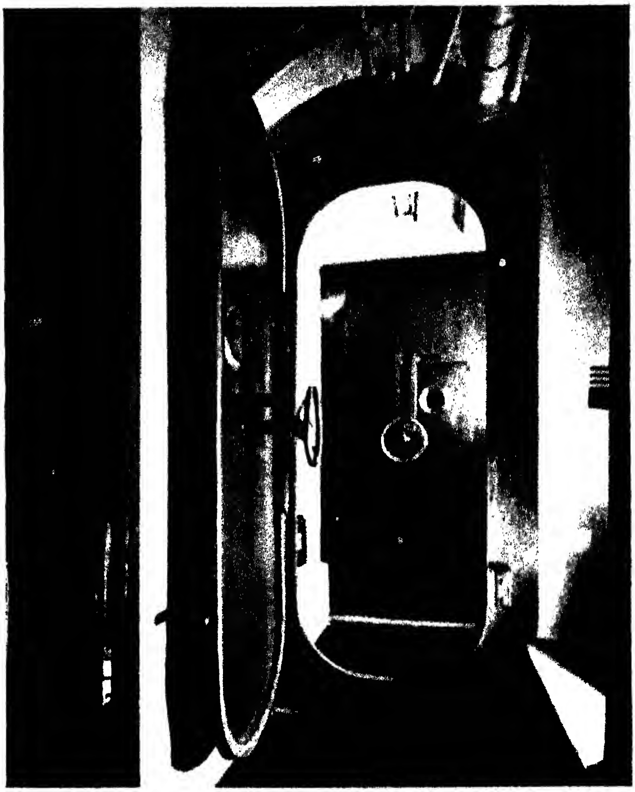


FIG. 88.—The Carrier Engineering gas-tight and splinter-resisting door.

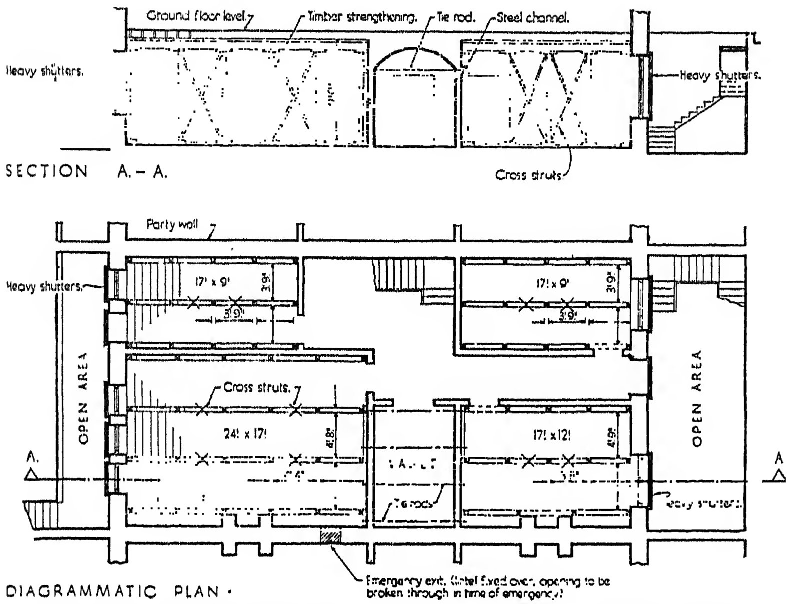


FIG. 102.—Example of typical basement strengthened with timber for a debris load of 400 lb. per sq. ft.

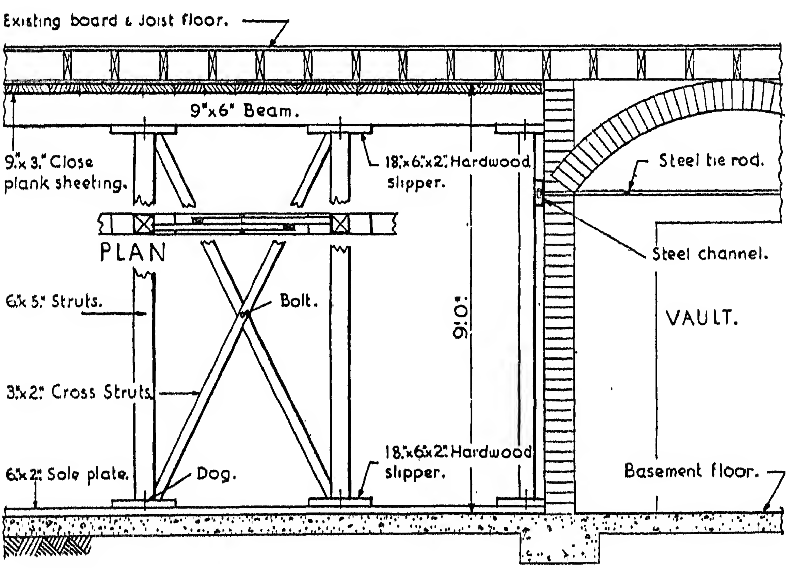
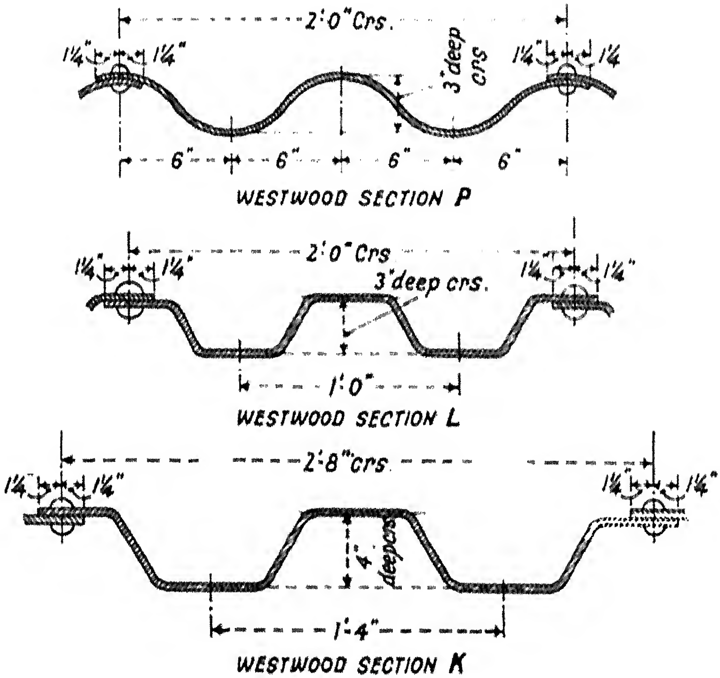


FIG. 103.—Details of timber strutting.



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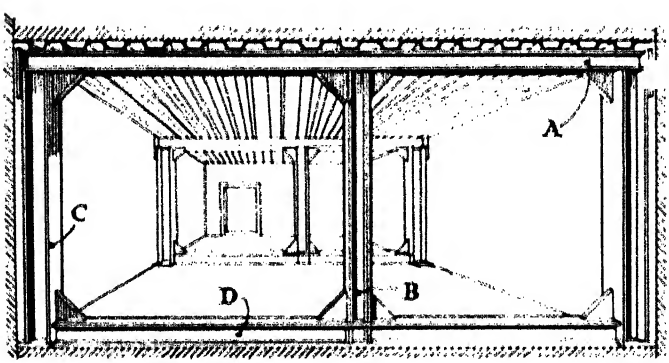


②

FIG. 104.—Strong form of steel frame shelter construction in an existing building using steel columns and beams and having sheet steel centering and concrete infillings.

Steel

For Steel Strutting. Larger spans would be more economic. Assuming 10 ft. centre to centre is adopted for the supports, the data given in Table LXXV will be found of use. If instead of the construction of a demolition slab on the floor over the shelter supplementary flooring is wedged up underneath, pressed steel corrugated plates generally as shown in Fig. 104 will be found of considerable use. The properties and costs are given in Table LXXX, and in Fig. 105.

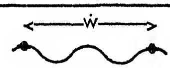
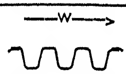
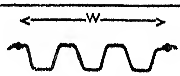
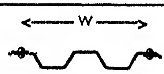
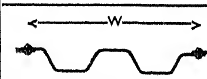
Section		Width (W)	Depth	Thick	Modulus of 1 plate	Weight □′ of area covered
P		2′ 0″	3″	$\frac{1}{8}''$ $\frac{3}{16}''$	2·5 in ³ 3·8 in ³	6·4 lbs. 9·8 ,,
N		1′ 0″	$2\frac{1}{2}''$	$\frac{1}{8}''$ $\frac{3}{16}''$	1·4 in ³ 2·1 in ³	9·0 ,, 13·5 ,,
M		1′ 6″	3″	$\frac{1}{8}''$ $\frac{3}{16}''$	2·9 in ³ 4·4 in ³	9·1 ,, 13·6 ,,
L		2′ 0″	3″	$\frac{3}{16}''$ $\frac{1}{4}''$	5·2 in ³ 7·0 in ³	10·6 ,, 14·0 ,,
K		2′ 8″	4″	$\frac{3}{16}''$ $\frac{1}{4}''$	9·7 in ³ 12·9 in ³	10·6 ,, 14·0 ,,

FIG. 105.—Properties of Westwood steel trough sections.

It is not possible to tabulate costs of the material delivered and erected since each job has its special features.

Steel Shores. A number of steel shores to proprietary designs are available, and Fig. 106 shows their use in shoring rooms for shelters in existing buildings.

The heads are normally made for 4 × 3 in. joists, and the shores are usually installed at 5 ft. centre to centre each way, the ceiling height being 7 ft. to 7 ft. 6 in.

The swivel shore is satisfactory for light loads and for use where the basement floor is not quite level.

Raking strains have to be provided for independently, but in *small* basements having *good solid walls* and a roof over resting well on to and reinforced with the walls, diagonal bracing may not be necessary.

Table LXXX

Section.	Weight in Pounds per Square Foot of Covered Area.	Thickness.	Moment of Resistance in inch tons per Foot Width.	Safe Distributed Loads in Hundredweights per Square Foot of Area Covered. Span. 5 ft.	6 ft.	8 ft.	10 ft.	12 ft.	15 ft.	Cost per Square Foot Painted one Coat Holed at 12-in. Pitch complete with Bolts. Loaded at Works. s. d.
P	6·5	1/8″	11·5	6·1	4·2	2·4	1·5	1·0	0·7	1 9
P	9·8	3/16″	17·0	9·2	6·4	3·6	2·3	1·6	1·0	2 3
P	13·0	1/4″	23·0	12·3	8·5	4·8	3·1	2·1	1·4	2 9
P	16·2	5/16″	28·0	15·3	10·6	6·0	3·8	2·7	1·7	3 3
P	19·4	3/8″	34·5	18·4	12·8	7·2	4·6	3·2	2·0	3 9
L	10·6	3/16″	23·5	12·6	8·7	4·9	3·2	2·2	1·4	2 6
L	14·0	1/4″	31·5	16·8	11·7	6·6	4·2	2·9	1·9	3 0
L	17·4	5/16″	39·5	21·0	14·6	8·2	5·2	3·7	2·3	3 6
K	10·6	3/16″	32·5	17·4	12·1	6·8	4·4	3·0	1·9	2 6
K	14·0	1/4″	43·5	23·2	16·1	9·1	5·8	4·0	2·6	3 0
K	17·4	5/16″	54·5	29·0	20·2	11·3	7·3	5·0	3·2	3 6
K	20·8	3/8″	65·5	34·8	24·2	13·6	8·7	6·0	3·9	4 0

The moments of resistance and the safe loads in the above tables are based on a working stress of 9 tons per sq. in.

In A.R.P. Memorandum No. 10 the Home Office give details of strutting to basements by means of steel tubular props.

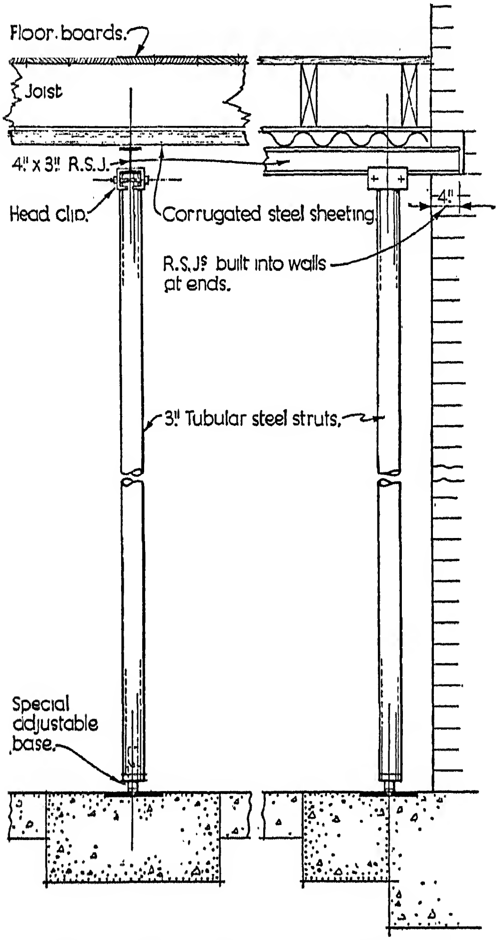


FIG. 106.—Details of steel strengthening.

SPECIAL STEEL STRUTTING FOR BASEMENTS

List of Parts

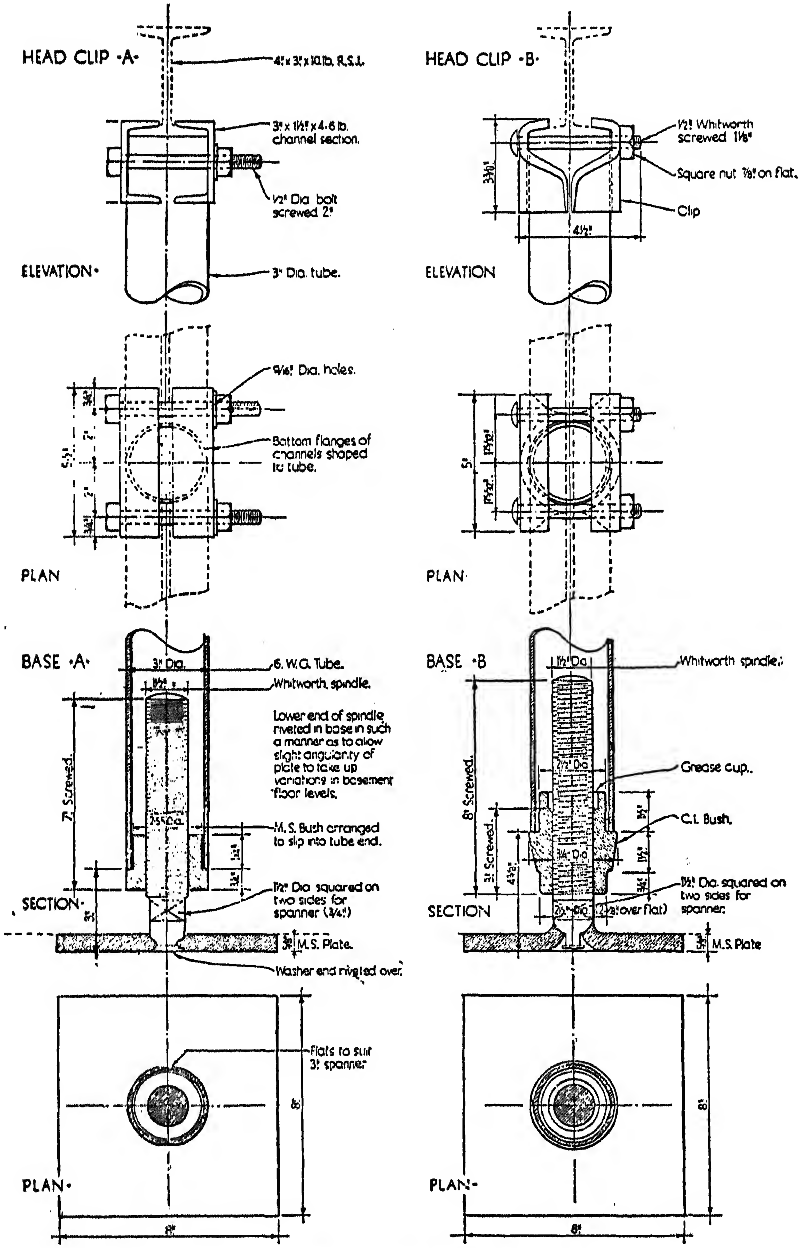
The following is a list of the items provided for the strutting of basements by steel :—

1. Corrugated steel sheets, 14 B.G. finished black, with

Table LXXXI

Steel-frame Shoring for Shelters

No.	Demolition Load.	A.	B.	C.	D.	Price in Pence per Square Foot of Floor Area.
1	15 tons point . .	14″ × 5½″ × 40 lb.	6″ × 5″ × 25 lb.	5″ × 4½″ × 20 lb.	14″ × 5½″ × 40 lb.	33
2	20 ,, ,, . .	15″ × 6″ × 45 lb.	8″ × 5″ × 28 lb.	5″ × 4½″ × 20 lb.	15″ × 6″ × 45 lb.	30
3	200 lb. per sq. ft. .	10″ × 4½″ × 25 lb.	6″ × 5″ × 25 lb.	5″ × 4½″ × 20 lb.	10″ × 4½″ × 25 lb.	25
4	300 ,, ,, .	10″ × 4½″ × 25 lb.	8″ × 5″ × 28 lb.	5″ × 4½″ × 20 lb.	10″ × 4½″ × 25 lb.	26
5	400 ,, ,, .	12″ × 5″ × 32 lb.	8″ × 6″ × 35 lb.	5″ × 4½″ × 20 lb.	12″ × 5″ × 32 lb.	31
6	500 ,, ,, .	12″ × 5″ × 32 lb.	8″ × 6″ × 35 lb.	6″ × 5″ × 25 lb.	12″ × 5″ × 32 lb.	33
7	600 ,, ,, .	13″ × 5″ × 35 lb.	8″ × 6″ × 35 lb.	6″ × 5″ × 25 lb.	13″ × 5″ × 35 lb.	35
8	700 ,, ,, .	14″ × 5½″ × 40 lb.	15″ × 6″ × 45 lb.	6″ × 5″ × 25 lb.	14″ × 5½″ × 40 lb.	39
9	800 ,, ,, .	14″ × 5½″ × 40 lb.	14″ × 6″ × 46 lb.	8″ × 5″ × 28 lb.	14″ × 5½″ × 40 lb.	40
10	900 ,, ,, .	15″ × 6″ × 45 lb.	12″ × 6″ × 54 lb.	8″ × 6″ × 35 lb.	15″ × 6″ × 45 lb.	47
11	1,000 ,, ,, .	15″ × 6″ × 45 lb.	12″ × 6″ × 54 lb.	8″ × 6″ × 35 lb.	15″ × 6″ × 45 lb.	47



NOTE: Head clips A & B and bases A & B are alternatives. Either head clip can be used with either base.

FIG. 107.—Details of tubular steel struts.

5/5 in. corrugations, in lengths of 6 ft., 7 ft. or 8 ft., and in width 2 ft. 4 in.

2. Rolled steel joists 4 in. × 3 in. × 10 lb. finished with one coat of red oxide or black bitumastic solution.

3. Struts, consisting of a head clip, a steel tube and a screw-jack base, the latter itself comprising a screw spindle riveted to a base plate and carrying a threaded bush.

The parts and their relationship *in situ* are shown in Figs. 106 and 107.

Placing the Sheets

The corrugated steel sheets are to be placed in close contact with the existing ceiling joists, the corrugations and joists running parallel.

The sheets are to be lapped at the edges where they meet, the minimum lateral lap being one corrugation, and the minimum longitudinal lap being 1 ft. 6 in.

The longitudinal lap is to be so arranged that it is supported by a rolled steel joist, the centre line of which is not less than 9 in. distant from the end of either sheet.

Placing the Joists

The rolled steel joists are to be placed at right angles to the direction of the floor joists, at a maximum spacing of 5 ft. from centre to centre, with a maximum distance of 1 ft. 6 in. between the side wall and the centre of the nearest joist, and are to be cut and pinned into the supporting walls a minimum of 4½ in. at either end.

Placing and Erecting Struts

The struts shall be placed at not more than 5 ft. centres along each joist, and the distance between the side wall and the nearest line of struts shall not exceed 1 ft. 6 in.

The struts are erected as follows :—

The bush is located at the bottom of the screw-spindle, which, together with the attached base-plate, should then be placed in its proper position on the floor. The tube is placed over the spindle to rest upon the shoulders of the bush and adjusted at the top to engage the head clip by which it is affixed to the joist. Adjustment for height is made by turning

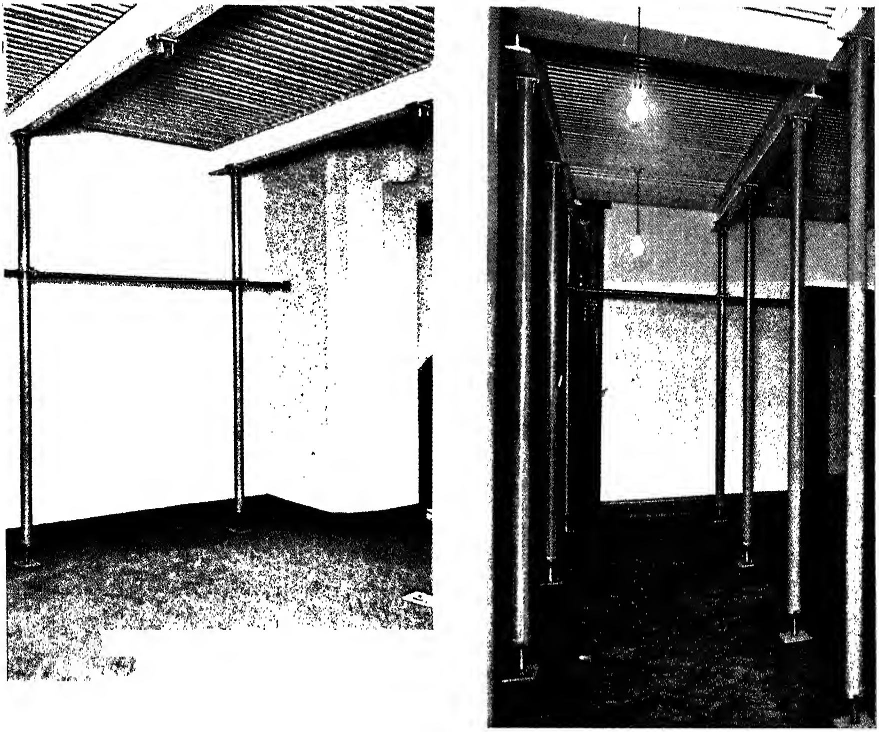


Fig. 108.—Basement at 66 Cannon Street strengthened by Mills struts, beams and sheeting. Note clear "peace time" floor space on left.

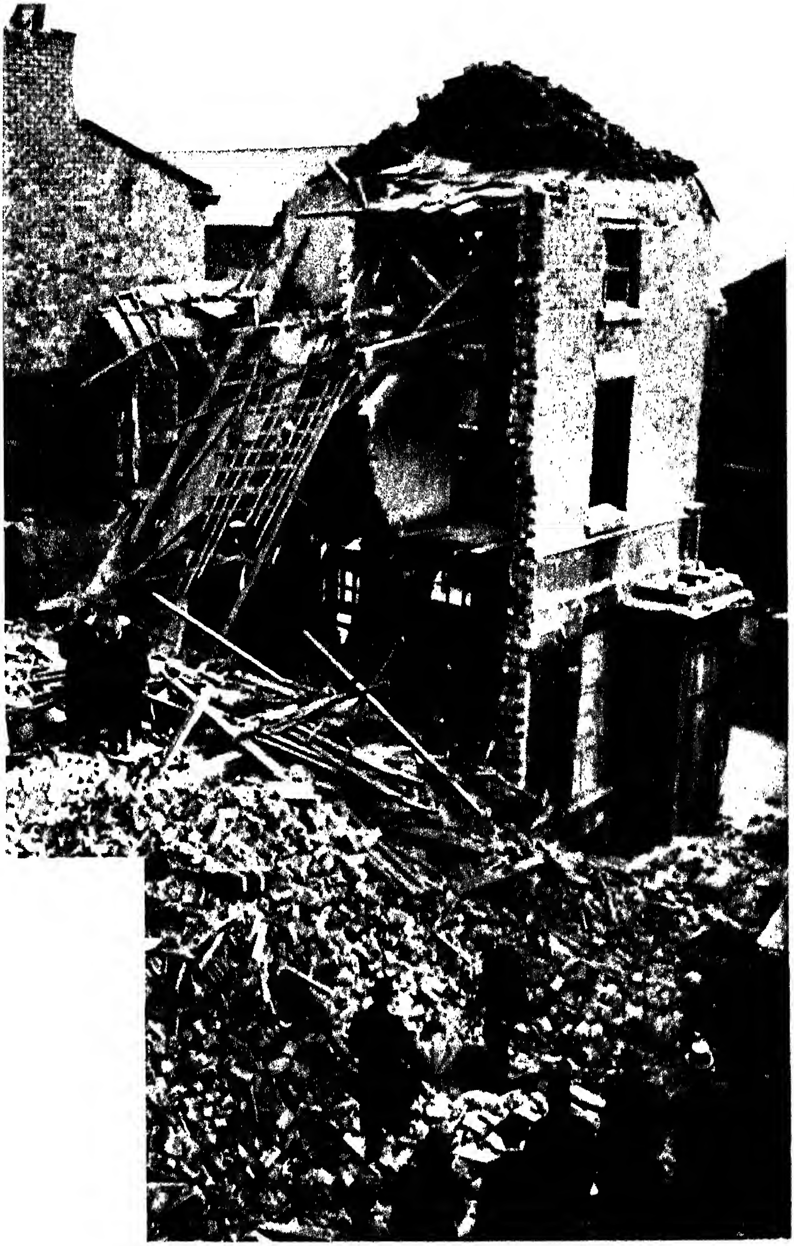


FIG. 109.—Showing remains of a three-storey building after explosion in a Home Office test. The basement shelter strutted with steel tubular struts was undamaged.

the bush on the spindle, and the adjustment should be such that the joist and tube are in direct contact, without the tube exerting any material upward pressure.

The strut should finally be checked to see that it is truly vertical and in overall height not greater than 9 ft.

If the struts are not to be erected until the basement is needed for shelter, then the positions of head clips and bases should be clearly marked on the joist and floor, and the struts removed to suitable storage.

It may be desirable in some cases to mark the struts with references showing their location.

Size of Building and Size of Basement Shelter

The special steel strutting of the type here described is intended for use in the basements of the smaller type of houses with timber floors and not more than three storeys over the basement. The size of basements must be such that the maximum dimension parallel to the line of the rolled steel joist shall not exceed 13 ft., and the maximum dimension at right angles to the rolled steel joist shall not exceed 18 ft.

Fig. 108 shows the strengthening of a basement at 66 Cannon Street, London, using struts made by the Mills Scaffold Co., Hammersmith. By September, 1938, this basement had been strengthened to the H.O. requirements, and at the same time strengths were calculated to allow a clear basement during peace time.

Intermediate struts can be introduced rapidly by the office staff in an emergency.

Fig. 109 shows the remains of a three-storey building after explosion during a Home Office test. The basement shelter strutted with steel tubular struts was undamaged.

Note the entry being made through the coal-hole adapted for use as an emergency exit.

Pre-cast Reinforced Concrete Beams

There is no doubt that pre-cast reinforced concrete beams are eminently suited to the work of roofing a basement shelter.

The Siegwart Fireproof Floor Co. Ltd. have designed suitable units, and these are illustrated in Figs. 110 and 111.

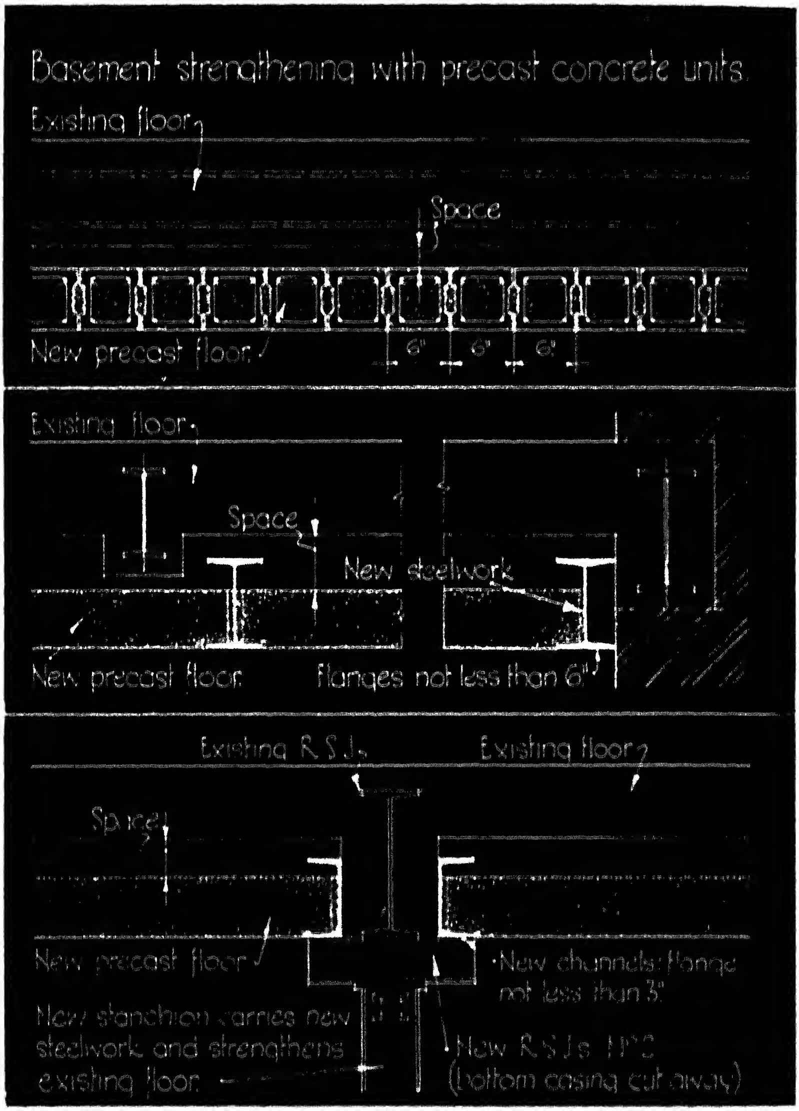


FIG. 110.

The advantages of this system are :—

1. No interference with occupation of floors above.
2. The new floors are permanent, fire-resisting and gas-proof.

3. The soffits are mesh reinforced to minimise scabbing and they require no plastering.

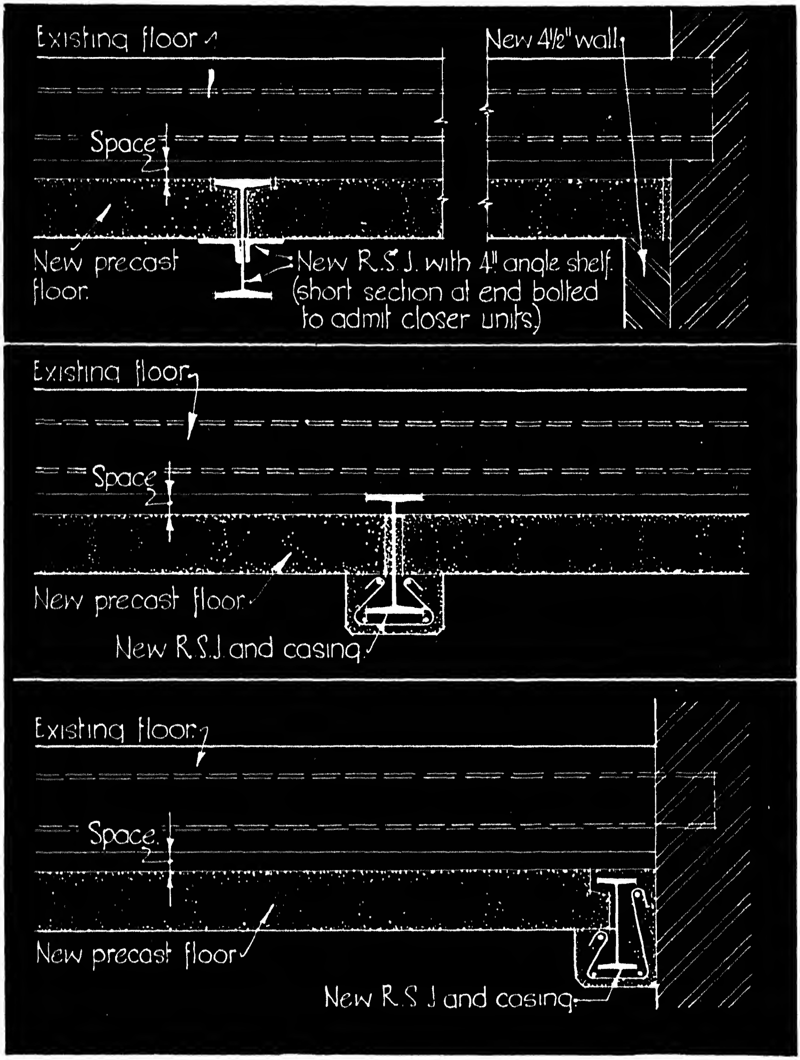


FIG. 111.

4. The fixing is quick and dry and requires no centering or site poured concrete.

TABLE LXXXII

MAXIMUM FREE SPANS FOR VARIOUS DEBRIS LOADINGS, USING SOLID BEAMS

Thickness of beam.	Weight in lb./sq. ft.	Loads in lb. per sq. ft. Spans in feet and inches.		
		200	300	400
5¼"	63	8' 4"	7' 0"	6' 3"
6½"	78	10' 6"	9' 0"	8' 0"
7½"	90	12' 1"	10' 5"	9' 4"
8¼"	99	13' 3"	11' 6"	10' 3"
9¼"	111	14' 10"	12' 11"	11' 7"

Examples

Fig. 112 shows plan of basement of typical city premises having ground, four floors and roof over. The construction is

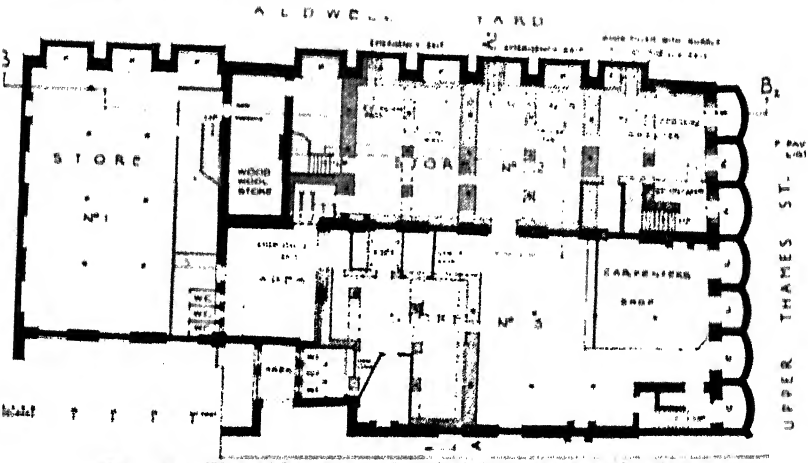


FIG. 112.—Plan of basement of typical City premises showing construction of shelter.

slated roof on timber trusses, timber floors on steel beams bearing directly on external brick walls and internal cast-iron columns. The arrangement to provide accommodation for a staff of 250 of both sexes is indicated.

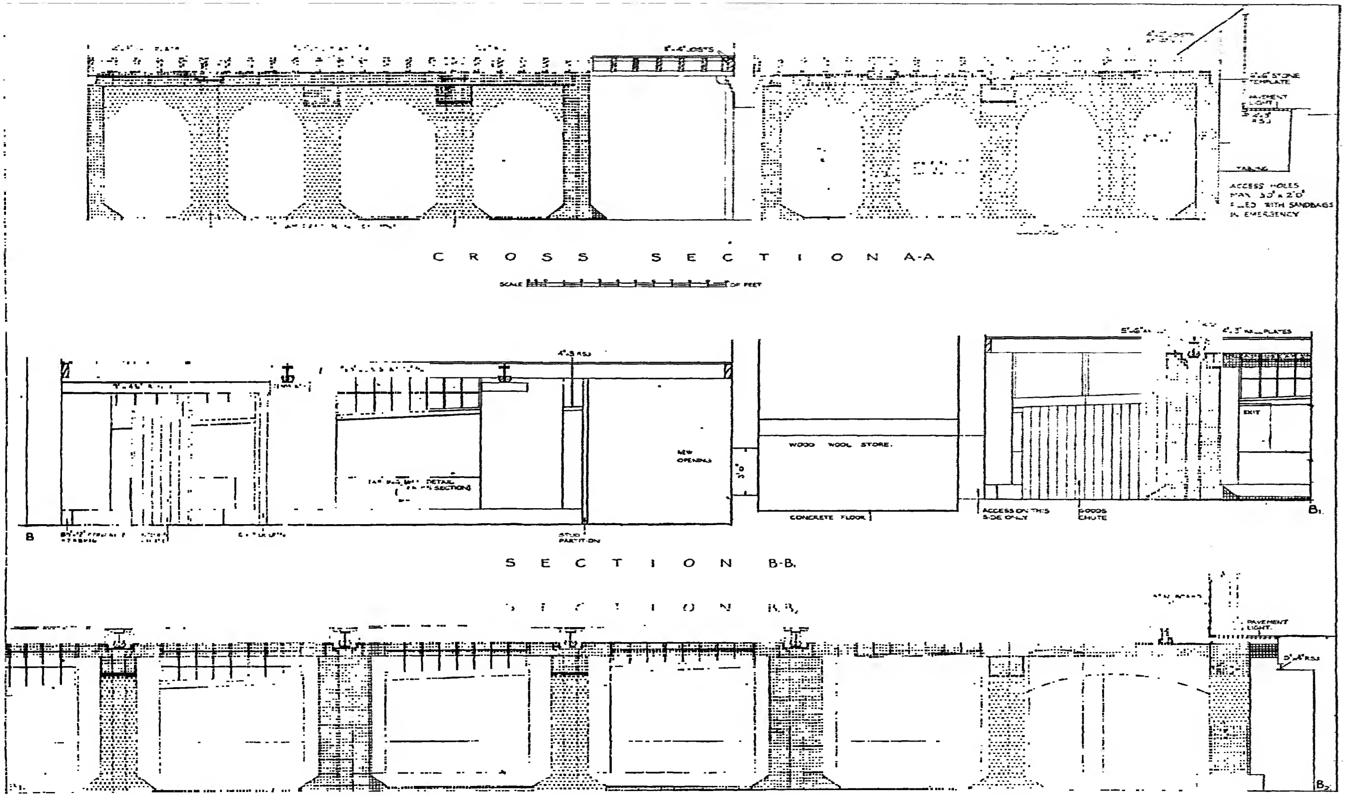


FIG. 113.—Section of basement shown in Fig. 112 and indicating vulnerable nature of pavement lights.

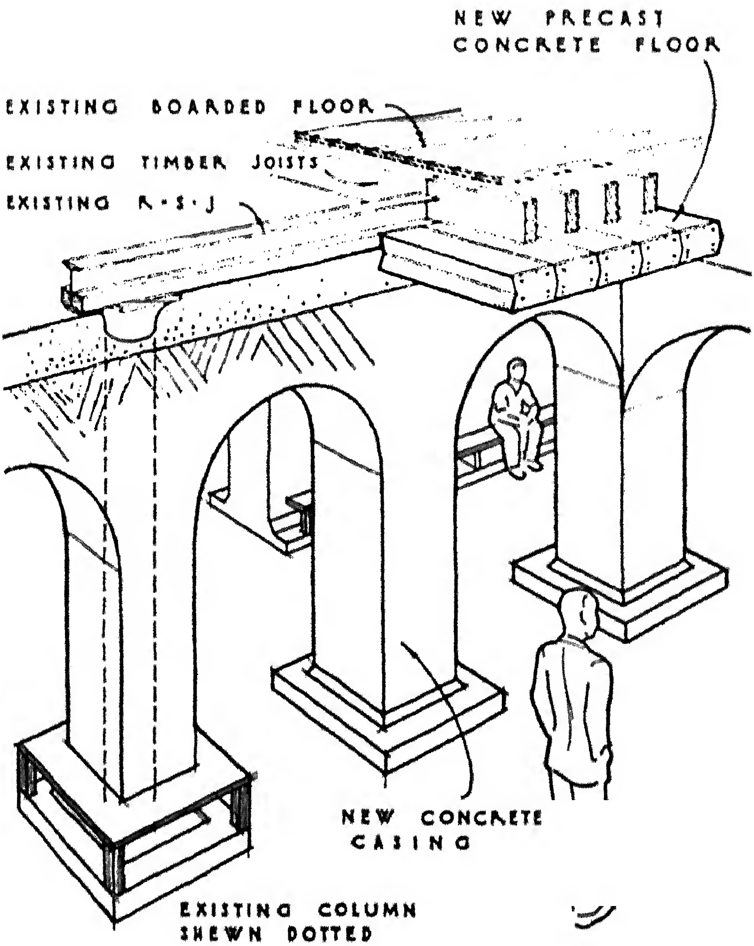


FIG. 114.—Sketch showing arched concrete supports for pre-cast "demolition" beams.

Fig. 113 shows section of basement and indicates the vulnerable nature of the pavement and stallboard lights, and the method of encasing the cast-iron columns with aluminous cement and concrete arched over at the top to provide stable support for the pre-cast demolition slab erected under the existing floor.

Fig. 114 shows sketch of the arrangement. The cost works out at £12 per person accommodated, including all equipment, gas and fire-fighting appliances.

CHAPTER VIII

INDIVIDUAL SHELTERS

THE Civil Defence Act (see Chapter XII) lays down the Government's shelter policy.

The following points are, however, of interest in the consideration of the provision of individual shelters :—

1. Communal air raid shelters for the whole of the general public are neither practicable nor desirable, except in special cases.

2. The greatest danger is from high explosive bombs, followed by incendiary and gas bombs, in that order.

In their report—now issued as a White Paper, Cmd. 5932, H.M. Stationery Office—the Technical Committee appointed by the Lord Privy Seal to consider certain aspects of the problem of air raid shelters, state in conclusion :—

"We would respectfully state our firm conviction that the magnitude and urgency of this problem are so great that the utmost possible use should be made of the resources of every trade that can be employed upon the work in the construction of all the forms of shelter accommodation dealt with hereinbefore to the utmost extent and at the utmost speed possible, viz. :—

"(*a*) Pressed and rolled sectional shelters.

"(*b*) Propped basements.

"(*c*) 'Pill-boxes.'

"(*d*) Permanently strengthened lower floors of blocks of flats and tenements.

"(*e*) Permanently strengthened basements of shops, offices, and large houses.

"(*f*) Communal shelters and trenches.

"Only by these means can we conceive that the necessary accommodation will be made available within a reasonable period of time."

TABLE LXXXIII

AIR RAID SHELTERS (NOT PROOF AGAINST DIRECT HITS BY HIGH EXPLOSIVE BOMBS)

Table showing that the smaller the unit size of shelter the less the total casualties.

Probability of casualties from direct hits per 100 H.E. bombs falling within fifteen miles of Charing Cross. Area = 707 square miles. Population = 8,400,000 (all in shelters).

Size of shelters: Based on $7\frac{1}{2}$ sq. ft. floor area per person.

A direct hit is assumed to make casualties of all persons in the shelter.

Definition of direct hit: (A) On shelter only. (B) Within 50 ft. of edge of shelter.

Capacity per shelter (persons).	Number of shelters required.	Yards between shelters (centre to centre).	Sq. ft. of shelter per 100 sq. ft. = Direct hits per 100 bombs.		Total "direct-hit" casualties per 100 bombs dropped.	
			A.	B.	A.	B.
1,000	8,400	549	0·32*	1·31	320	1,310
500	16,800	388	,,	1·94	160	970
200	42,000	245	,,	3·47	64	694
100	84,000	174	,,	5·66	32	566
50	168,000	123	,,	9·96	16	498
25	336,000	87	,,	18·02	8	451
10	840,000	55	,,	40·50	3·2	405
5	1,680,000	39	,,	75·22†	1·6	376

* *I.e.*, 1 bomb in every 313 scores a "Direct Hit."

† *I.e.*, 75 bombs in every 100 scores a "Direct Hit."

Note. The shelters are assumed to be circular in plan and evenly distributed at the centres of hexagonal areas, which is theoretically the most economical arrangement.

3. It is not feasible to attempt protection from direct hits by high explosive bombs, but protection from the infinitely greater risks of splinters, blast and falling masonry is comparatively easy.

4. The most effective means of protection is to disperse the target. In other words, the more the populace can be educated to remain at home, or at their places of employment, in small private splinter-proof refuges, the fewer the casualties likely to be caused by air raids.

The table above, reproduced by kind permission of the Cement and Concrete Association, shows why a large number of small shelters is better than a smaller number of larger shelters.

Both the Structural Code under the Civil Defence Act and

the H.O. Memorandum on basement shelters require that: "In order to minimise the number of casualties likely to result from a direct hit, shelters should preferably be limited to parties not exceeding 50 persons. The distance between shelters should be not less than 25 ft. in any direction, and 40 to 50 ft. spacing is preferable where space permits."

When considering the problem of shelter protection, the degree of protection aimed at must always be borne in mind, and in this connection the policy of the Air Raid Precautions Department may be stated to be as follows:—

Degrees of Protection

1. In order to obtain complete protection against the effects of a direct hit by a 500 lb. high explosive bomb, fitted with a semi-armour-piercing nose, a thickness of overhead covering of about 60 ft. of earth or 15 ft. of highly reinforced concrete is required. Except in those places where such a covering already exists, shelters to give this degree of protection will rarely be used.

Similarly, complete protection against the effect of direct hits by high explosive bombs lighter than 500 lb. also requires considerable thicknesses of overhead covering of earth or reinforced concrete. Owing to the heavy cost involved, it will not generally be practicable to provide such protection.

2. It is recommended, therefore, that the normal form of shelter accommodation should be constructed so as to provide protection against

(i) Blast, splinters and gas, and

(ii) Either (*a*) the lightest incendiary bomb; or
(*b*) incendiary bombs up to 25 lb. in weight.

Such shelters should also be protected from the effects of the demolition of the superstructure due to high explosive bombs.

Dispersion

The German official regulations, as well as the recommendations of the Home Office, indicate that shelter accommodation should be designed to accommodate not more than fifty persons in each separate compartment save in exceptional circumstances where the local conditions would justify a greater number.

Where private or other shelter accommodation is not likely to be occupied by more than a few persons, and provided the occupants are not crowded together, no ventilation will normally be necessary for reasonable periods of occupation, even though the shelter accommodation may be rendered airtight.

Shelters provided for the civil population may be divided broadly into the following four categories :—

1. Private gas- and splinter-proof shelters in the home.

2. Gas- and splinter-proof shelters in factories, business premises, etc., or the smaller type of communal shelters in blocks of flats.

3. Gas- and splinter-proof shelters for the floating populations in the street ; and

4. Shelters affording a greater degree of protection for the essential services.

It is important to recognise that consideration of the question of protection does not indicate an exclusive choice of one particular type of shelter, but that there are wide degrees of variation.

Private Shelters

Whatever may be the distribution of the population in a city during working hours, at night the population is largely distributed, and the logical place for the air raid shelter is at the home.

Whatever public monies may be spent on the provision of emergency shelters, it is manifestly the duty of the householder to do all he possibly can by way of the provision of a suitable splinter-proof shelter at home for his family. Such a shelter is an assurance and is just as necessary as the carrying of life-boats at sea.

Full advantage should be taken of existing basements and shelters established as already described.

Fig. 115 shows a shelter as a basement in a semi-detached house. For the maximum protection of the building against incendiary bombs the loft should be cleared of stored material, the roof timbers treated with one or other of the fire-proofing methods described on p. 67, or painted with fire-resisting paint, or covered with asbestos paper, described on p. 191.

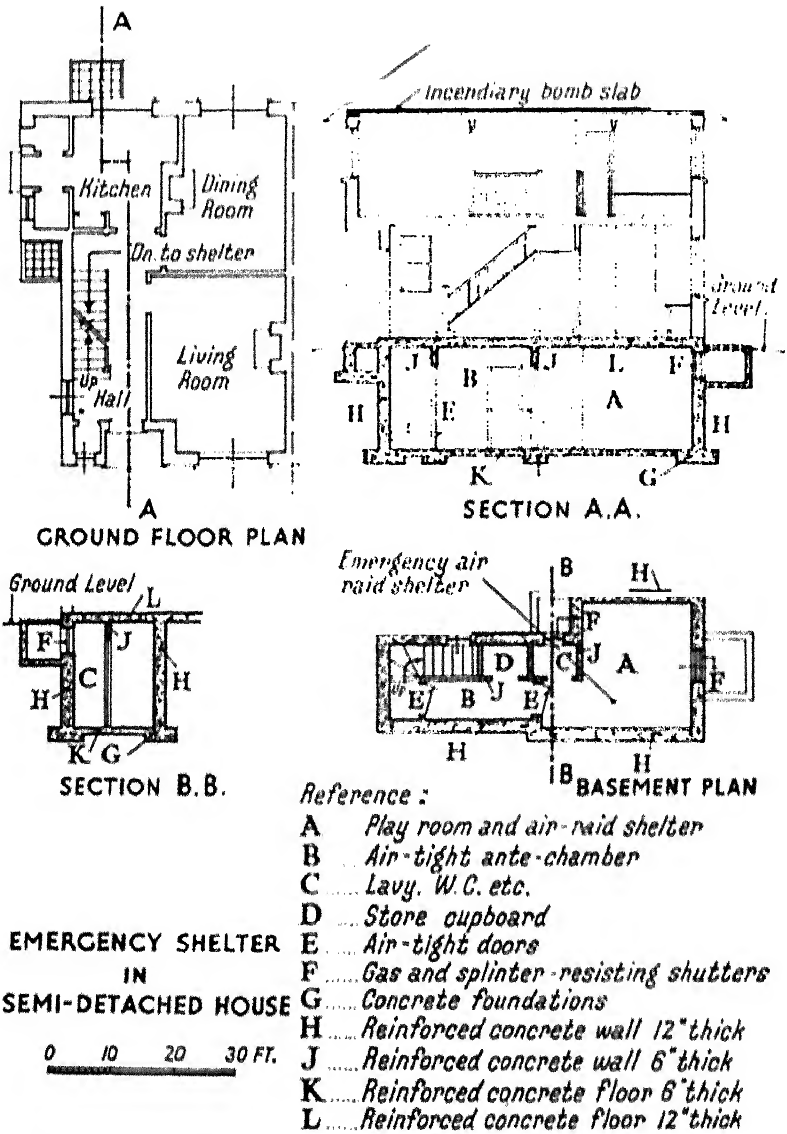


FIG. 115.—Emergency shelter constructed as basement in semi-detached house.

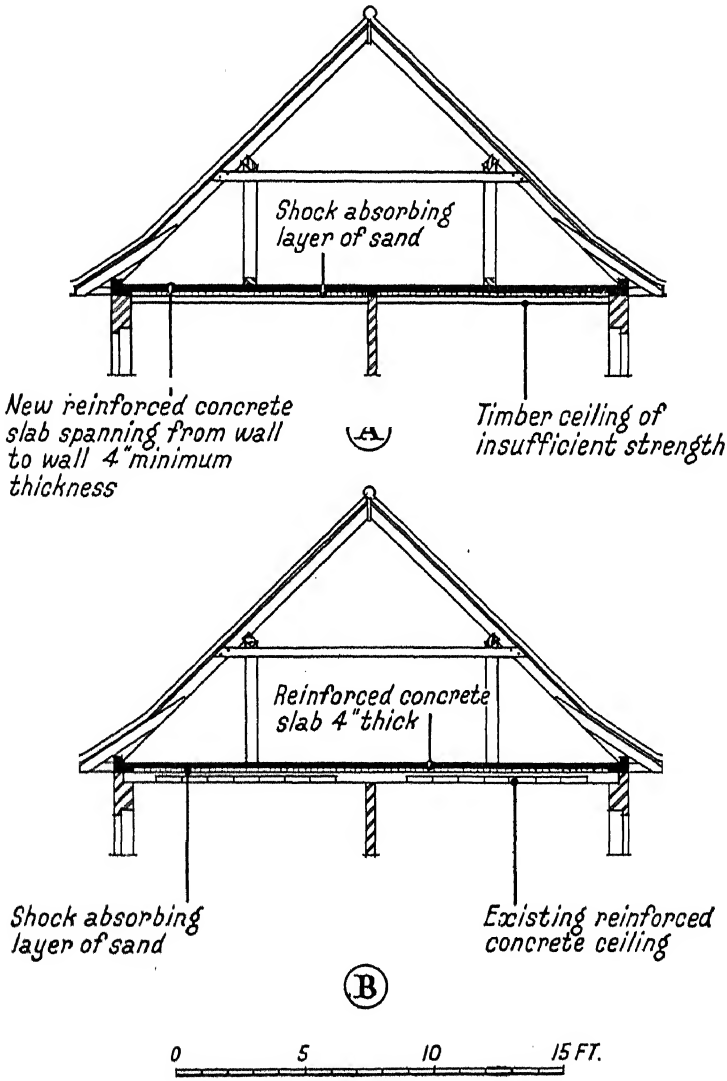


FIG 116.—Protection against kilo incendiary bomb.

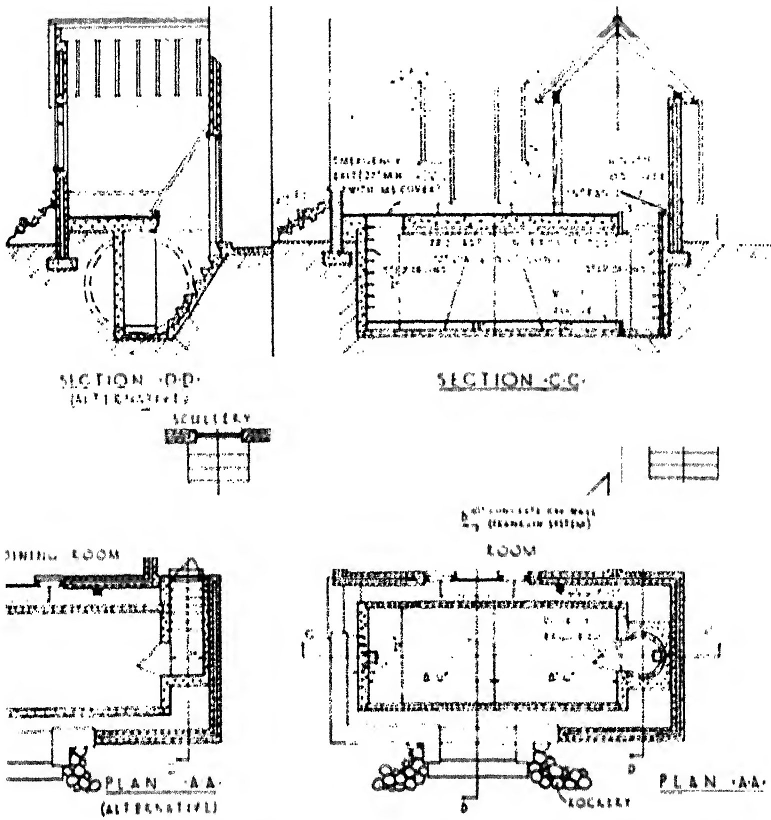


FIG. 117.—Splinter-proof private air-raid shelter giving a reasonable degree of protection from all hazards except direct hits by H.E. bombs. Maximum capacity with 16 ft. of 72 in. dia. concrete tubes, as shown, is twelve persons if entrances are left open and gas masks are worn.

The floor of the loft should then be protected with a slab of reinforced concrete at least 4 in. thick, constructed on a 2 in. layer of sand and spanning from wall to wall, generally as shown in Fig. 116.

The reinforcement in the basement wall and floor constructions should consist of ⅜ in. diameter mild steel bars laid in both directions at 9 in. c/c., forming a 9 in. square mesh. At all angles reinforcement should be well tied together to ensure continuity of structure. Two extra ½ in. trimmer bars should be inserted all round door and window openings.

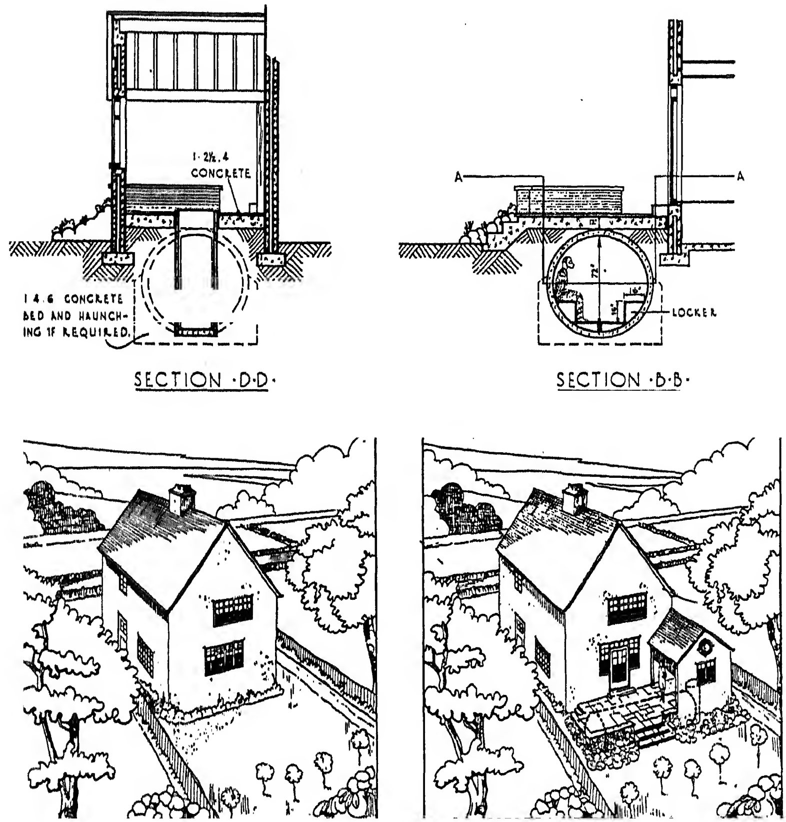


FIG. 118.—Further details of shelter shown in Fig. 117. This figure shows how the amenities may be improved by constructing a paved terrace or loggia over the concrete tube shelter. See notes, p. 286.

The doors should be of the gas-tight type, as shown in Fig. 26, and the window emergency exit should be protected with gas-proof and splinter-resisting shutter, generally as shown in Fig. 74.

The emergency outlet should also be screened with sand-bags to a thickness of 2 ft. 6 in. The cost of incorporating such a shelter in a new house, as indicated in Fig. 115, would be approximately £145 extra to that of a similar house without a basement.

Figs. 117 and 118, reproduced by kind permission of the

Cement and Concrete Association, show a type of external splinter-proof air raid shelter giving a reasonable degree of protection from all hazards except direct hits by large high explosive bombs.

The maximum capacity with 16 ft. of 72-in. diameter concrete tube, as shown, is twelve persons if entrances are left open and gas masks are worn. The capacity is less if entrances are closed to exclude gas (see Tables LXXXIV and LXXXV below).

Table LXXXIV

CAPACITIES OF CONCRETE TUBE SHELTERS OF THE TYPE SHOWN IN FIGS. 117, 118 AND 119 ON BRITISH HOME OFFICE BASIS OF 75 SQ. FT. INTERIOR SURFACE AREA PER PERSON FOR THREE HOURS' CONTINUOUS OCCUPATION, THE SHELTER BEING CLOSED AND UNVENTILATED

Ref.	Shelter (horizontal).		Entrance (vertical).		Approx. surface area.	Three-hour cap. (persons).	Capacity if ventilated with 150 cu. ft. per hour.
	Length.	Diameter.	Length.	Diameter.			
A.	8′	72″	8½′	27″	250 sq. ft.	3·3	10 (in 2 rows).
B.	16′	,,	,,	,,	400 ,,	5·3	20 ,,
C.	8′	78″	9′	,,	280 ,,	3·8	10 ,,
D.	16′	,,	,,	,,	440 ,,	5·9	21 ,,
E.	8′	84″	9½′	,,	310 ,,	4·1	16 (in 3 rows).
F.	16′	,,	,,	,,	485 ,,	6·5	24 ,,
G.	8′	90″	10′	,,	335 ,,	4·5	16 ,,
H.	16′	,,	,,	,,	525 ,,	7·0	26 ,,

Table LXXXV

CAPACITY OF CLOSED UNVENTILATED SHELTERS ACCORDING TO THE FRENCH FORMULA (BASED ON CUBIC CAPACITY)

Size of shelter (Ref. Table LXXXIV).	A.		C.	D.	E.		G.	H.
Persons accommodated .	3·3	5·3	3·8	5·9	4·1	6·5	4·5	7·0
Cubic capacity in cub. ft. .	260	485	310	585	345	645	395	750
Hours of safe occupation .	1·69	1·96	1·58	2·12	1·80	2·12	1·88	2·29

The use of pre-cast concrete pipes affords a very convenient method of constructing family air raid shelters, as shown in Figs. 117–121.

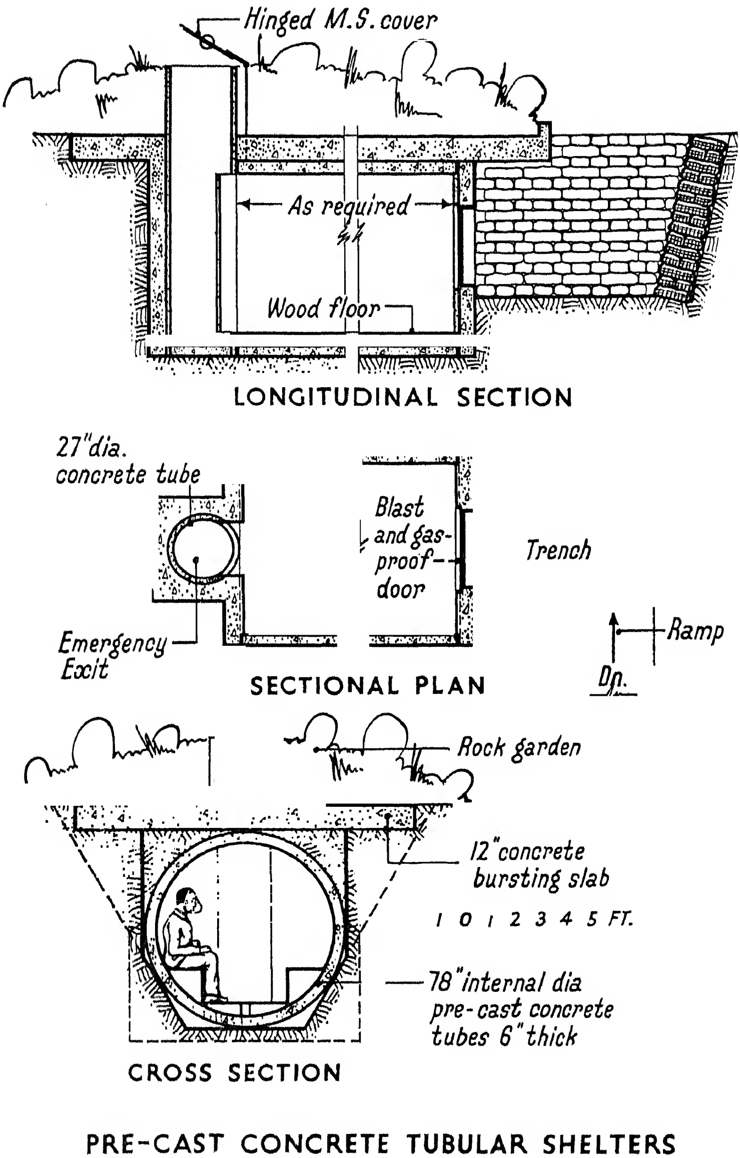


FIG. 119.—Details of a very strong and simple type of pre-cast concrete tubular shelter affording a high degree of protection and suitable for extension to accommodate fifty persons.

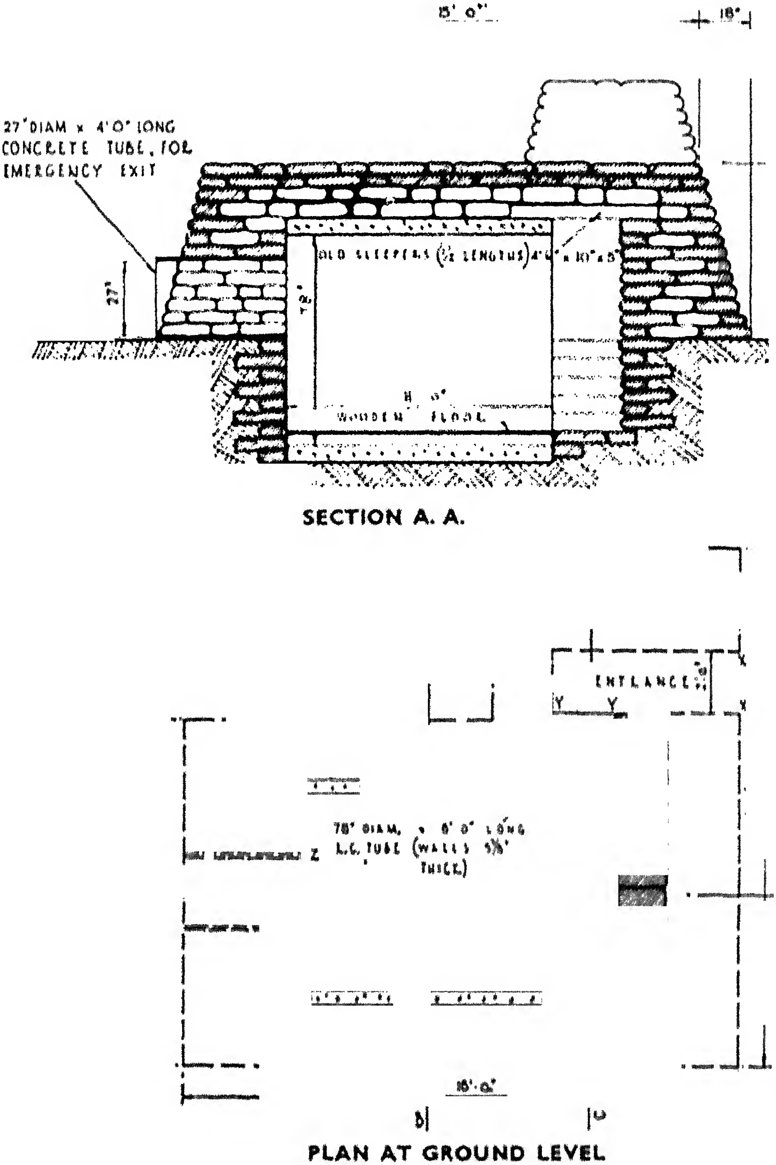


FIG. 120.—Splinter-proof air raid shelter for six persons and suitable for well-drained sites. Pre-cast reinforced concrete tubes are placed in the excavation and built round with sand-bags as shown. Those hatched are filled with concrete.

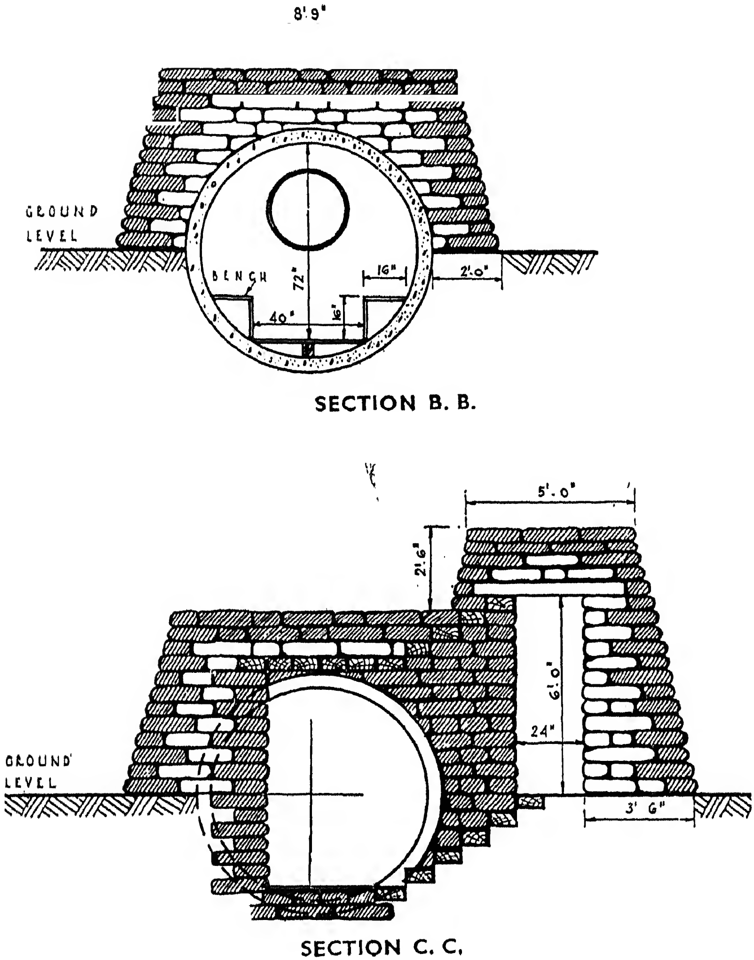


FIG. 121.—Further view of the shelter shown in Fig. 120. It will be noted that no shuttering or formwork is used in concreting and the shelter can be constructed with unskilled labour.

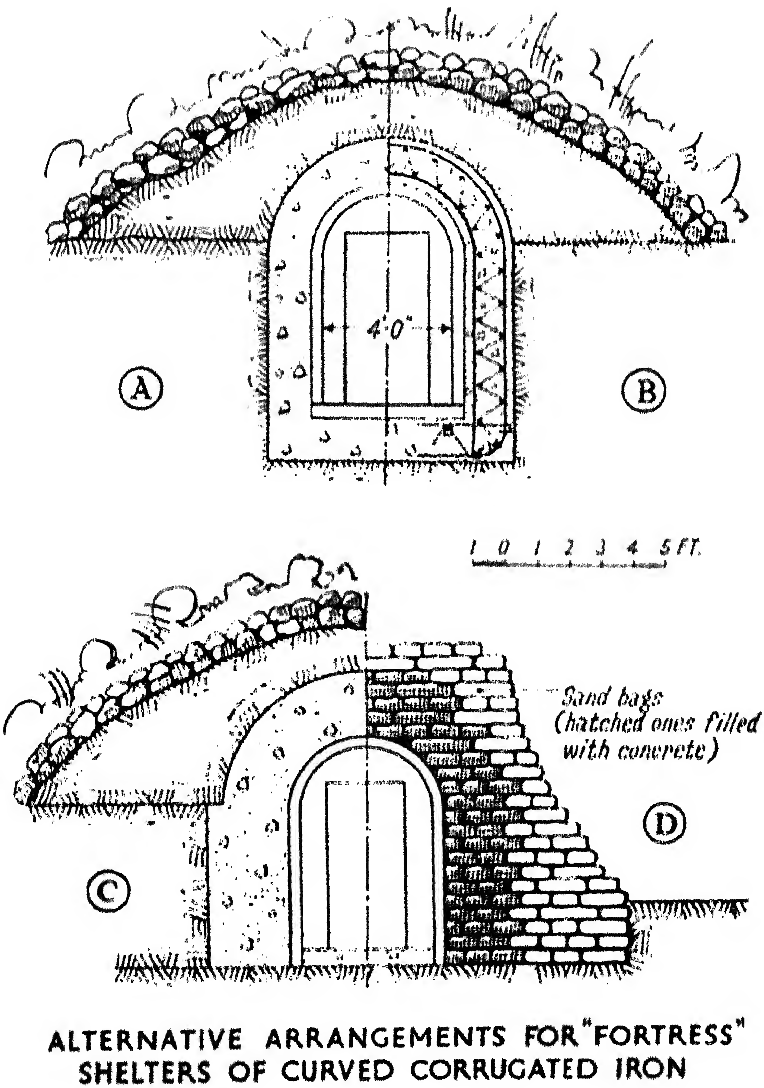


FIG. 122.—Type of domestic shelter showing alternative methods of installation of curved corrugated iron pre-fabricated shelter.

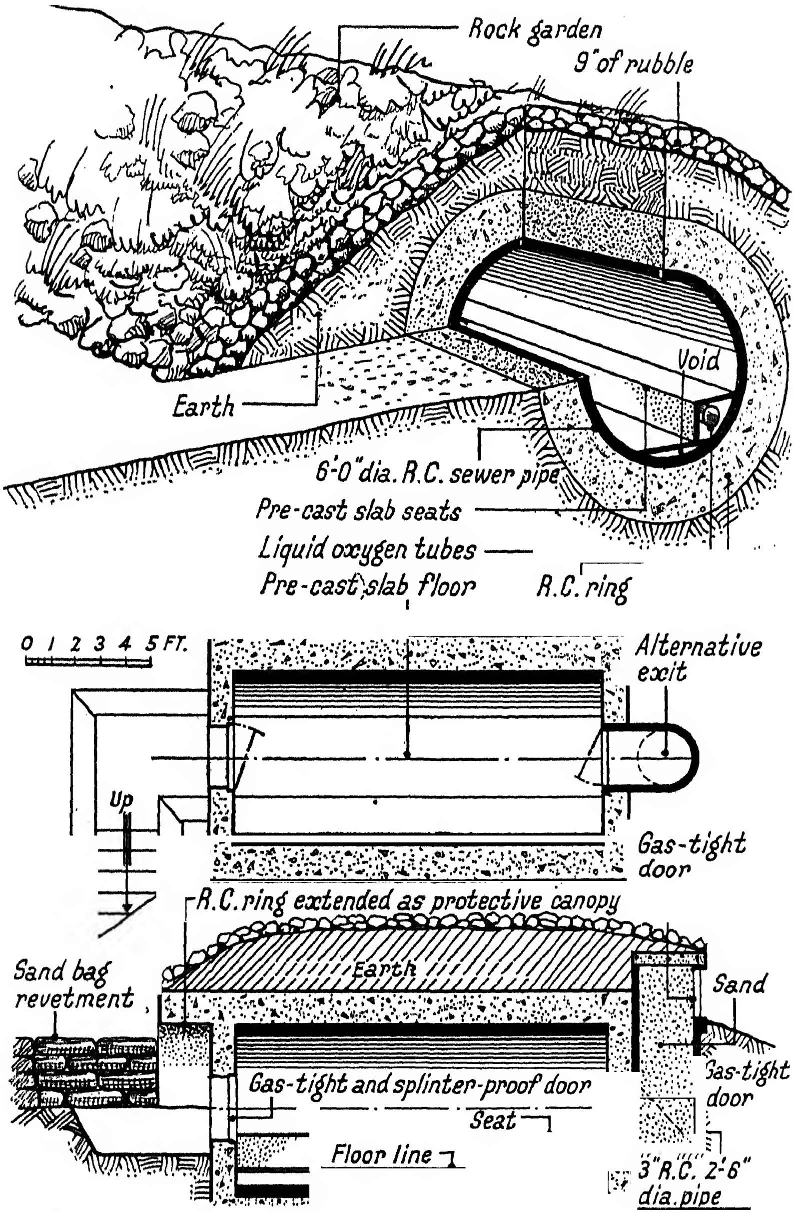


FIG. 123.—Improved tubular shelter affording a high degree of protection. Note the sand filling of the emergency exit as interior protection of the outlet (always somewhat vulnerable).

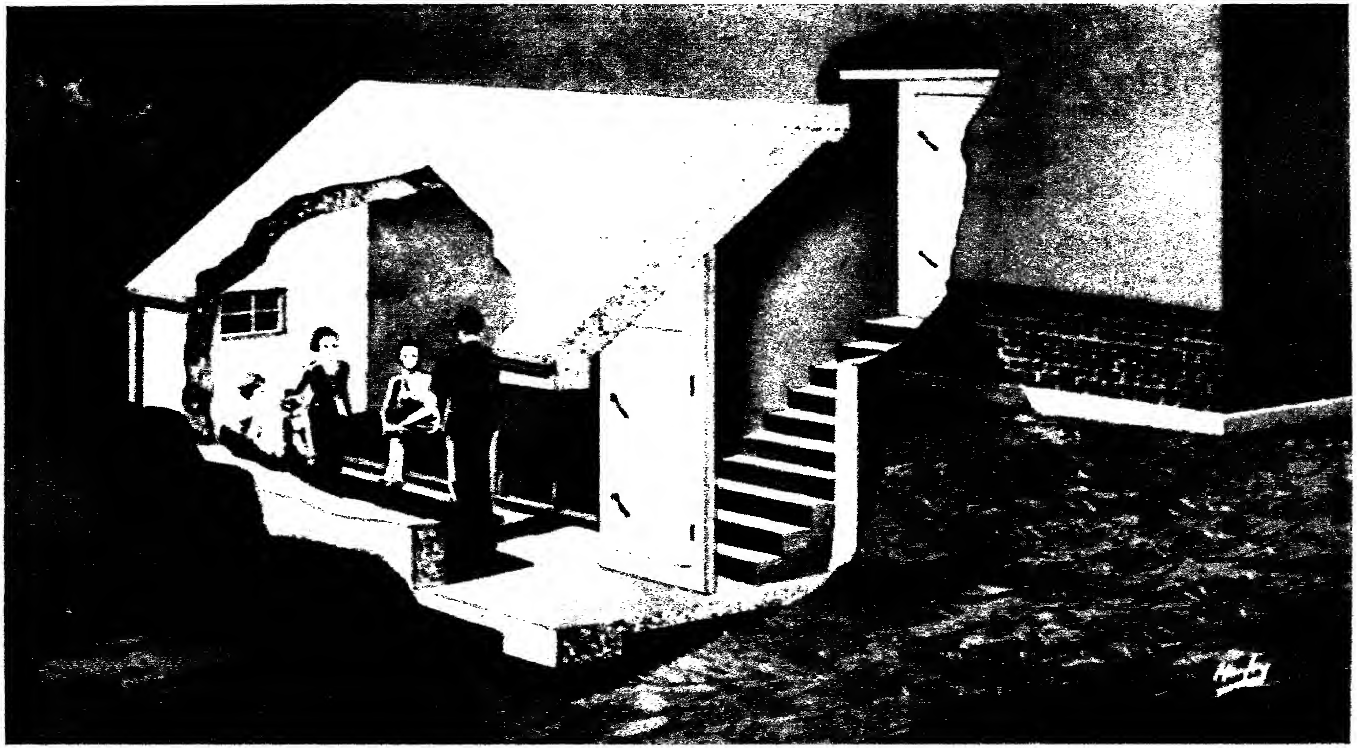


FIG. 125.—Lean-to type of domestic shelter.

for rates, and it is obviously desirable in the interests of civil protection to facilitate the passing of plans and to encourage owners to construct shelters by wholly or partially derating them.

Building societies should also be encouraged to advance loans on approved schemes for permanent shelters.

Fig. 123 shows an improved form of tubular concrete shelter.

NORCON AIR RAID SHELTERS

Tubular shelters completely buried under the ground, generally as illustrated in Fig. 124, 15 ft. long and 6 ft. diameter,

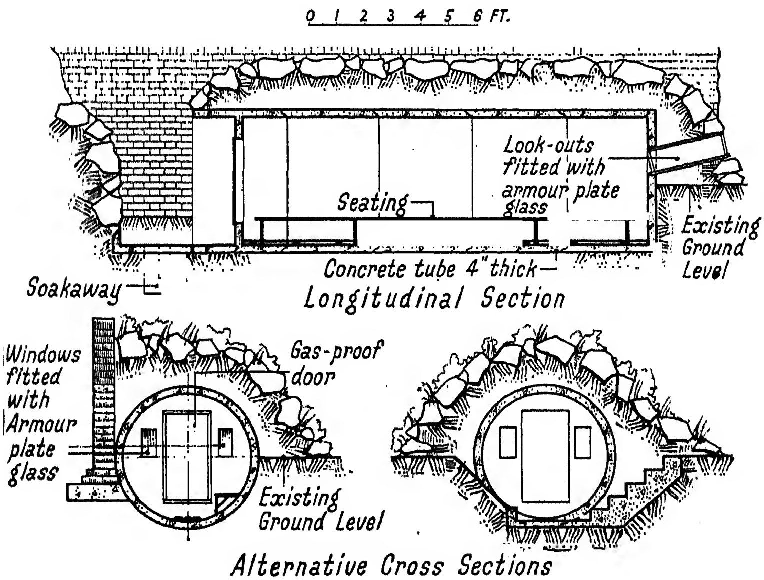


FIG. 126.—Small Norcon air raid shelter.

complete with gas-tight covers and equipment, but excluding electric light, would cost about £175, delivered and erected in the London district.

A new type of shelter, as shown in Fig. 126 and constructed of strongly reinforced concrete tubes, 54 in. in diameter and 4 in.

thick, can be supplied at a figure of £40, complete with door and armour-plate glass windows.

These shelters are 15 ft. long and accommodate 6 adults.

They can be supplied with lavatory accommodation and emergency exit at the opposite end to the entrance if desired.

Norcon Ltd. also supply a private type of tubular shelter—54 in. diameter, 9 ft. long with ends—delivered at site for £10 10*s*. Installation, doors and windows extra.

An appreciable point in favour of the smaller shelter is that it need be only half submerged, with a rockery constructed over the visible portion, without detracting in any way from the appearance of the garden; furthermore, in normal times the shelter can be utilised for the storage of garden implements, deck chairs, etc., and even for the storage of roots.

RIGBY PATENT R.C. SHELTERS

The general form of these shelters is shown on Fig. 127, from which it will be seen that the structure is of segmental section in the form of a gothic arch with domical ends struck to the same radius. It is made up of small portable sections of pre-cast concrete which when bolted together are capable of withstanding considerable pressure, since the whole structure when loaded is under compression.

The sections are pre-cast in precision moulds and are therefore interchangeable, the whole of the units being delivered for erection on site to specific instructions given by the manufacturers.

Additional protection in the form of layers of reinforced concrete and earth to any desired amount can be added, and for small individual shelters two ends can be erected together making a complete circle on plan.

Any length of gallery can be constructed simply by inserting intermediate parallel sections as required.

The internal dimensions of the new Rigby shelter are $6 \times 6 \times 6$ ft., and can seat four a side.

The slabs are in reinforced concrete 3 in. thick, and are erected with bitumen joints, end and side flanges being bolted. Additional thicknesses of concrete can be added as desired.

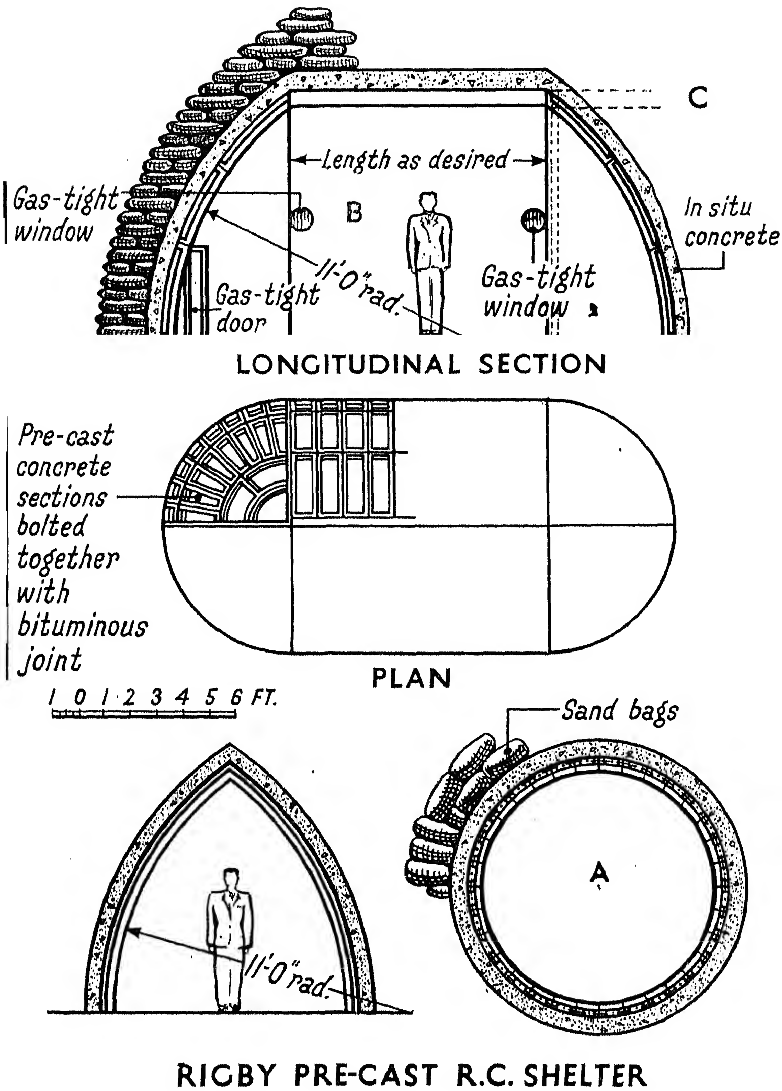


FIG. 127.—The Rigby pre-cast concrete shelter. Semi-circular arched sections on 3 ft. vertical side walls, making gallery 6 × 6 ft. now available.—Rigby (London) Ltd., 54 High Holborn.

The prices of Rigby shelters are as below :—

TABLE LXXXVI

	£	s.	d.
Type "A" shelter with top end area above 3 ft. Springing line open for use with gas masks	12	10	0
Type "B" with one gas-tight steel door and one reinforced concrete closed end	18	0	0
Type "C" with two gas-tight steel doors	22	10	0

The following are service and sales charges :—

	£	s.	d.
Excavation 6 ft. 6 in. × 6 ft. 6 in., 3 ft. deep, and replacing over top of shelter	2	10	0
Per each additional 2 ft. 6 in. in length, 3 ft. deep	0	12	6
Constructing reinforced foundation slab, $4\frac{1}{2}$ in. thick × 7 ft. × 7 ft.	2	10	0
Per each additional 2 ft. 6 in. length	1	0	0
Complete arched reinforced concrete sections, per foot run	1	13	4
Reinforced concrete vertical wall ends complete, less door opening, 3 × 2 ft.	2	10	0
Doors complete, $\frac{1}{4}$ in. steel plate with armoured-glass "look out," size 3 ft. × 2 in. (alternative inside or outside opening)	4	10	0
Extra for carrying materials and constructing through yard or house where mixer cannot be used	0	10	0
Constructing additional thickness of concrete over shell of 6 × 6 ft. shelter—3 in. thick	3	15	0
6 " "	7	0	0
Incorporating 1 in. steel mesh in above additional thickness	2	10	0
Erecting shelter, 6 × 6 ft., and caulking all sides and flanges and bolts in bitumen	2	10	0
Additional lengths *pro rata*.			
Caulking and fixing additional ends (two ends complete)	1	10	0

An advantage of this type of construction is that all units are of small size and capable of being handled by two men, so that the shelters can be erected in confined spaces in basements or in corridors with airtight bulkheads at intervals as desired.

STEEL TUBULAR SHELTERS

Fig. 128 gives details of a steel tubular shelter which, installed in the manner indicated, has exceptionally high splinter-proof and blast-resisting properties. It consists essentially of welded steel tubes of $\frac{1}{4}$ in. metal delivered in 4 ft. lengths and having an internal diameter of 4 ft. 6 in. to 5 ft. or 6 ft. as required.

Delivered with the lining are a hollow steel bulkhead already

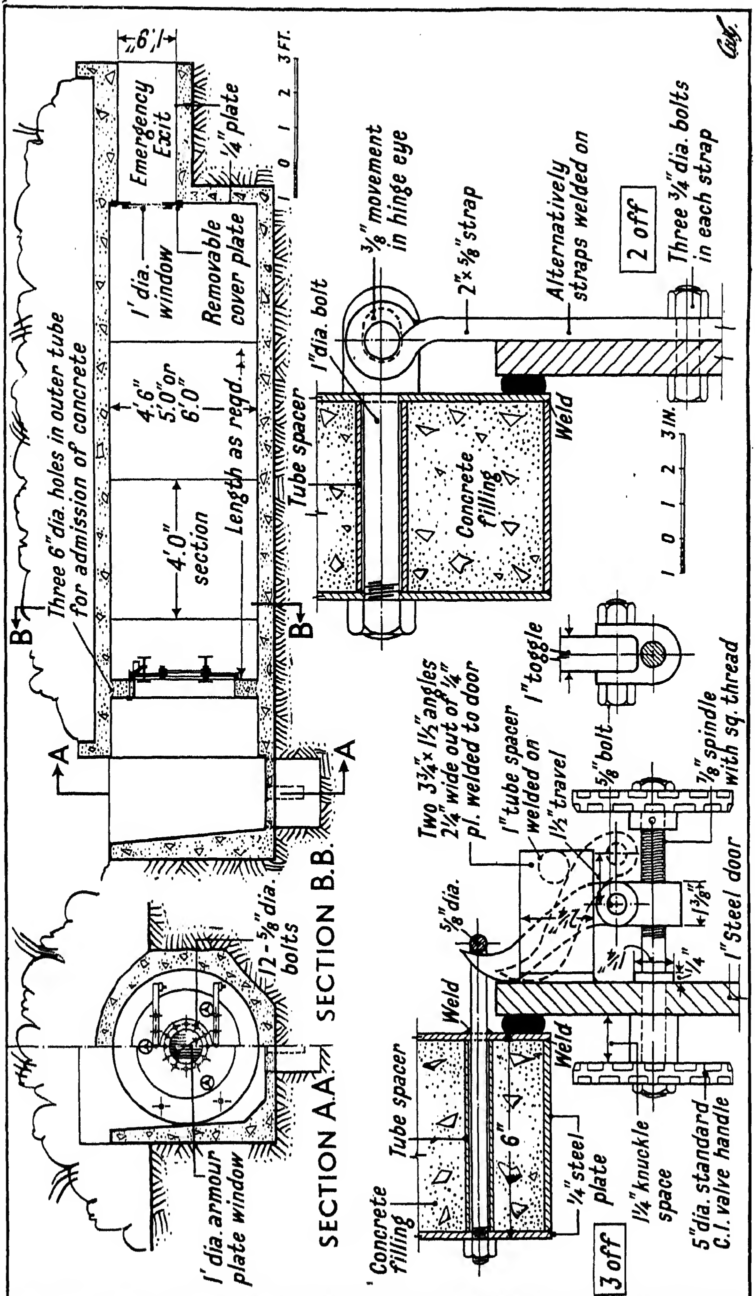


FIG. 128.—The steel tubular shelter with blast-proof splinter-resisting and gas- and water-tight door. (Note blast-proof windows and emergency exit.)

welded in the end section complete with blast-proof splinter-resisting cap and watertight door of steel 1 in. thick provided with a circular window of $\frac{3}{8}$ in. armour plate glass.

It will be seen on examination of the details that the door, which is 3 ft. diameter, is provided with four toggle-locking and wedging devices which can be operated from *both* sides of the door.

At the far end of the shelter a $\frac{1}{4}$ in. end plate is provided with removable cover over emergency exit leading to a 1 ft. 9 in. internal diameter steel tube, 4 ft. long. The emergency exit cover is also provided with a 1 ft. diameter blast-proof window. A method of installation is indicated in the Fig. 128, from which it will be seen that a trench, 4 ft. 6 in. deep, is dug to an octagonal section, a steel tube being installed therein with concrete surround. The excavated material is heaped over the crown of the shelter and finished with a rock garden.

The shelter can be supplied at the costs indicated in Table LXXXVII.

The installation costs will naturally depend upon local circumstances, but as no skilled trades are involved purchasers can instal these shelters themselves.

Seating accommodation, according to the requirements of the purchaser, can best be obtained locally.

This type of shelter, admitting daylight through the amply protected windows, very largely removes the feeling of claustrophobia so often experienced by individuals occupying close shelters.

The fact that the door opens inwards and that the gear is on the inside makes it less vulnerable to damage and blocking by *débris* exterior to the shelter. The accommodation provided by the shelter is given in Table LXXXVII, page 330.

The superiority of steel as a lining of shelters is generally recognised. The material is the most impervious to gases, the surface is hard and completely hygienic and being cold is best for the dissipation of heat and the condensation of the humidity in the enclosed air.

Government Surface Shelters

There is little doubt that a shelter properly constructed below ground affords the best protection, but in their pamphlet,

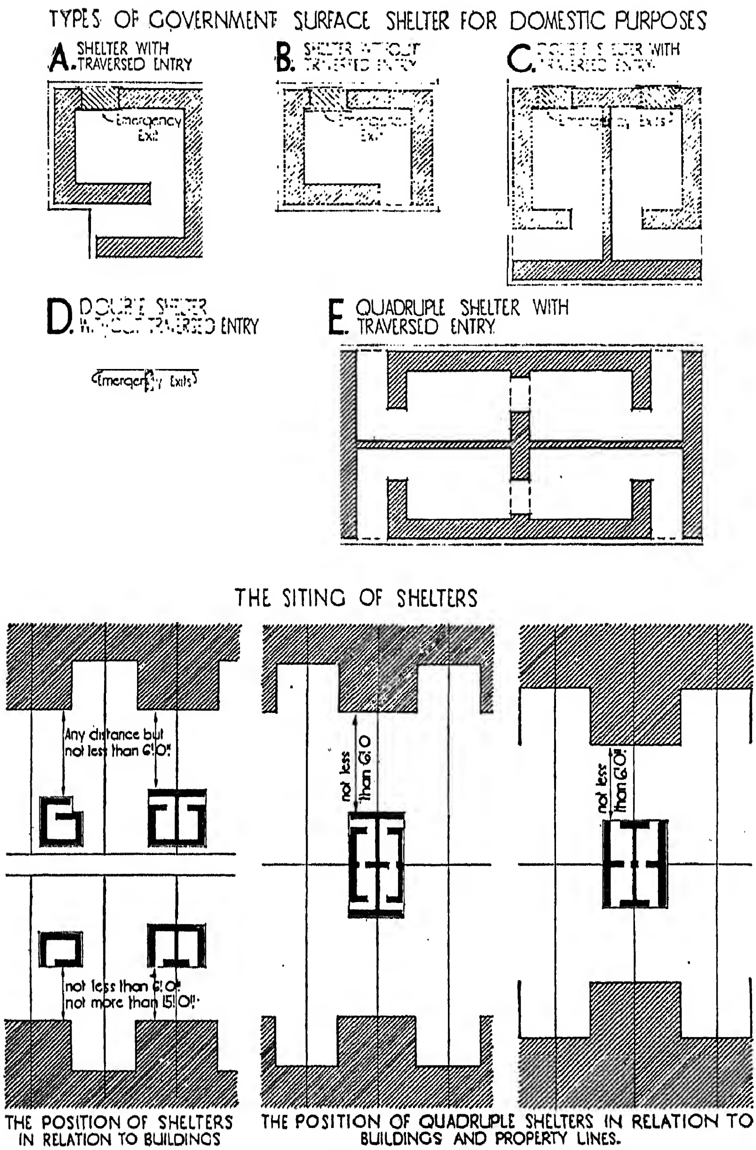

TYPES OF GOVERNMENT SURFACE SHELTER FOR DOMESTIC PURPOSES
A. SHELTER WITH TRAVERSED ENTRY
Emergency Exit
E. QUADRUPLE SHELTER WITH TRAVERSED ENTRY
THE SITING OF SHELTERS
Any distance but not less than 6'0"
not less than 6'0" not more than 15'0"
not less than 6'0"
not less than 6'0"
THE POSITION OF SHELTERS IN RELATION TO BUILDINGS
THE POSITION OF QUADRUPLE SHELTERS IN RELATION TO BUILDINGS AND PROPERTY LINES.

FIG. 129.

" Directions for the Erection of Domestic Surface Shelters,"[153] the Home Office make the following recommendations :—

SIZES OF DOMESTIC SURFACE SHELTERS, 6 FT. 6 IN. HIGH INSIDE

No. of persons.	Size.
6	4 ft. 6 in. × 6 ft. 6 in.
8	4 ft. 6 in. × 8 ft. 6 in.
10	4 ft. 6 in. × 10 ft. 6 in.
12	4 ft. 6 in. × 12 ft. 6 in.

Units of these sizes can be built together in double or quadruple sets.

Shelters which do not accommodate more than twelve persons are required to have not less than $3\frac{3}{4}$ sq. ft. per person floor space.

Arrangements and siting are shown in Fig. 129. When the shelter is within 6 to 15 ft. distance from the house it may be assumed that the house affords sufficient protection for the entrance.

At greater distances the entrance should be suitably " blinded " with splinter protection.

Materials

Concrete for Floors

112 lb. B.S.S. Portland cement to
12 cub. ft. clean hard aggregate containing 25 per cent. by volume of sand.

Concrete for Walls and Roof

112 lb. Portland cement.
3 cub. ft. approved clean sand.
5 cub. ft. well-graded + $\frac{3}{16}$ in. — $\frac{3}{4}$ in. hard aggregate.

Bricks

Burnt clay.
Sand lime to B.S.S. 187.
or Cement concrete to 1,500 lb. compression when wet.

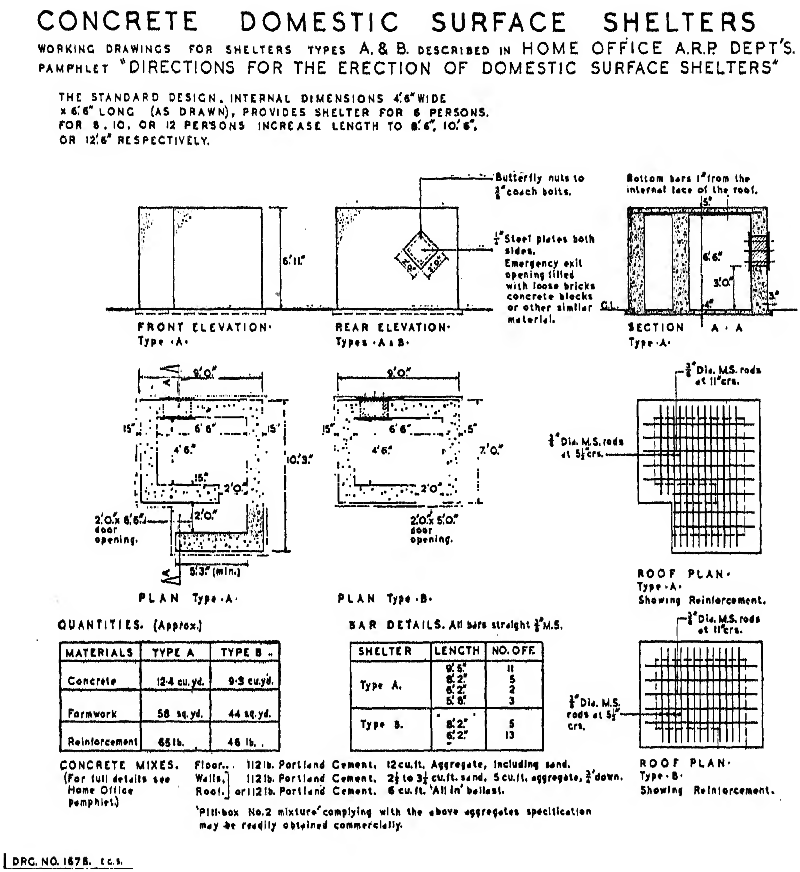


FIG. 130.—Working drawing of domestic surface shelter A and B.

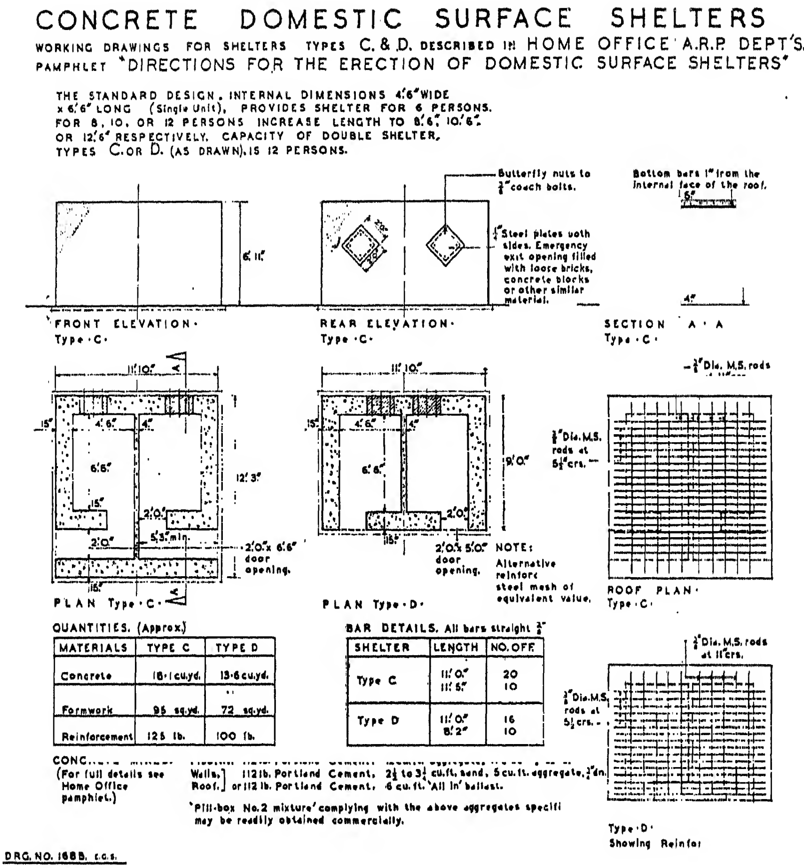
(*Courtesy C. & C. A.*)

Mortar

1 part Portland cement.
$\frac{1}{10}$ part lime putty or hydrated lime.
3 parts approved clean sand by volume.

Floor

Concrete, asphalte, gravel or hard earth.



MATERIALS	TYPE C	TYPE D
Concrete	18·1 cu.yd.	13·6 cu.yd.
Formwork	95 sq.yd.	72 sq.yd.
Reinforcement	125 lb.	100 lb.

SHELTER	LENGTH	NO. OFF
Type C	11' 0" 11' 5"	20 10
Type D	11' 0" 8' 2"	16 10

FIG. 131.—Working drawing of domestic surface shelter C and D

Walls

External. 13½ in. brickwork.
15 in. pre-cast concrete block.
or 15 in. *in situ* concrete.

Internal. 4½ in. brickwork.
or 4 in. concrete.

Roof

Reinforced concrete 5 in. thick (*in situ* or pre-cast with rebated joints).

⅜ in. rods at 5½ in. c/c on shorter span with usual distribution bars or equivalent mesh.

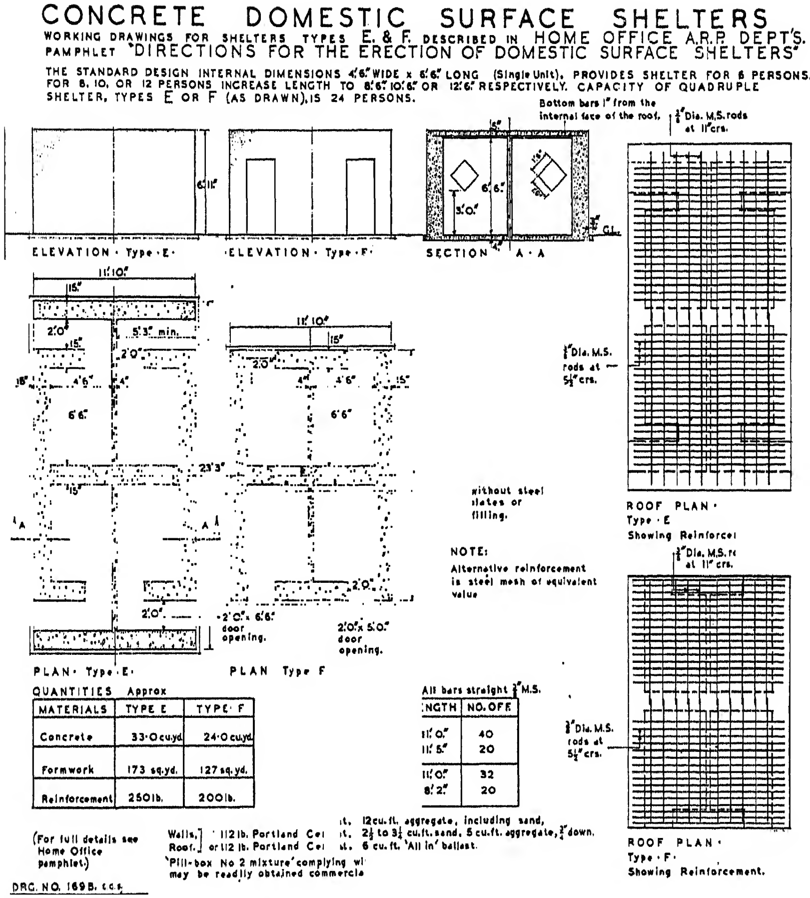


FIG. 132.—Working drawing of domestic surface shelter types E and F.

Lintels

6 in. deep concrete reinforced with three $\frac{3}{8}$ in. bars.

Emergency Exits

2 ft. square with $\frac{1}{4}$ in. mild steel plates on each side, bolted through with four $\frac{3}{8}$ in. bolts and space filled with rubble or gravel.

Working drawings are reproduced in Figs. 130, 131 and 132.

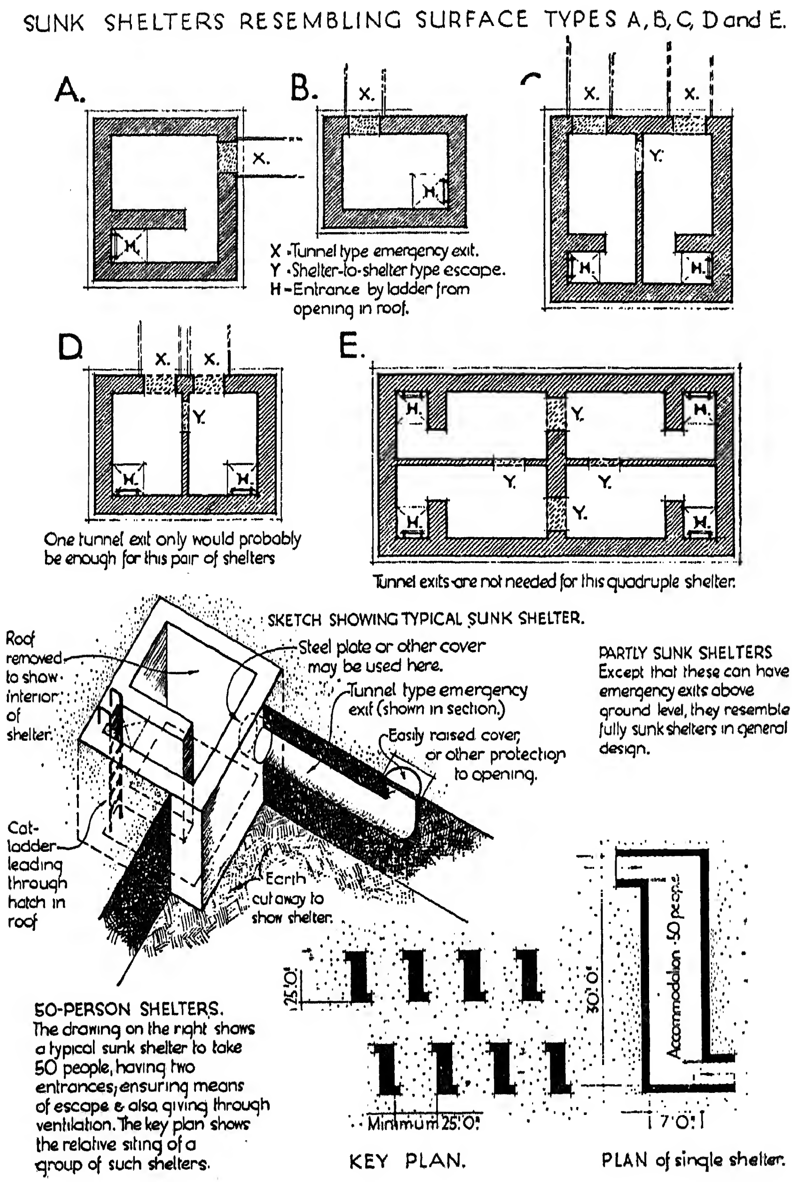
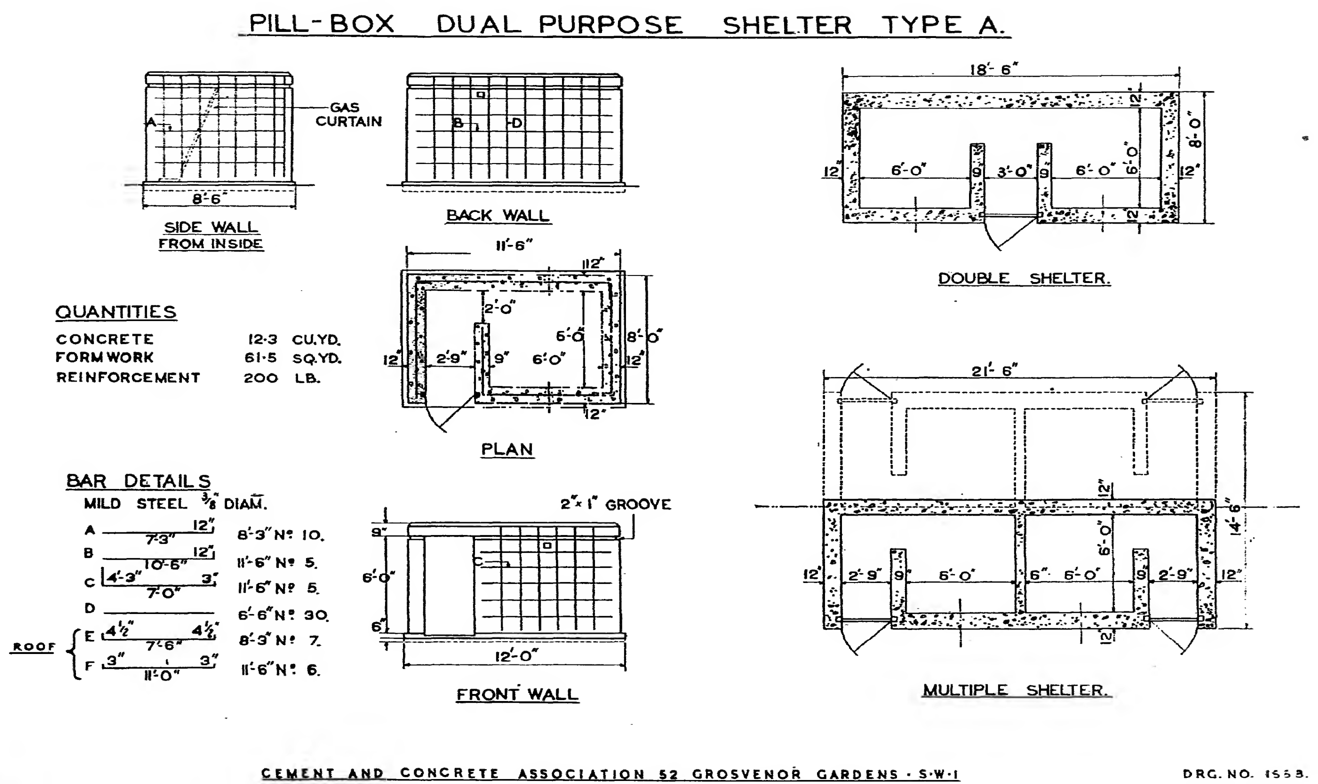


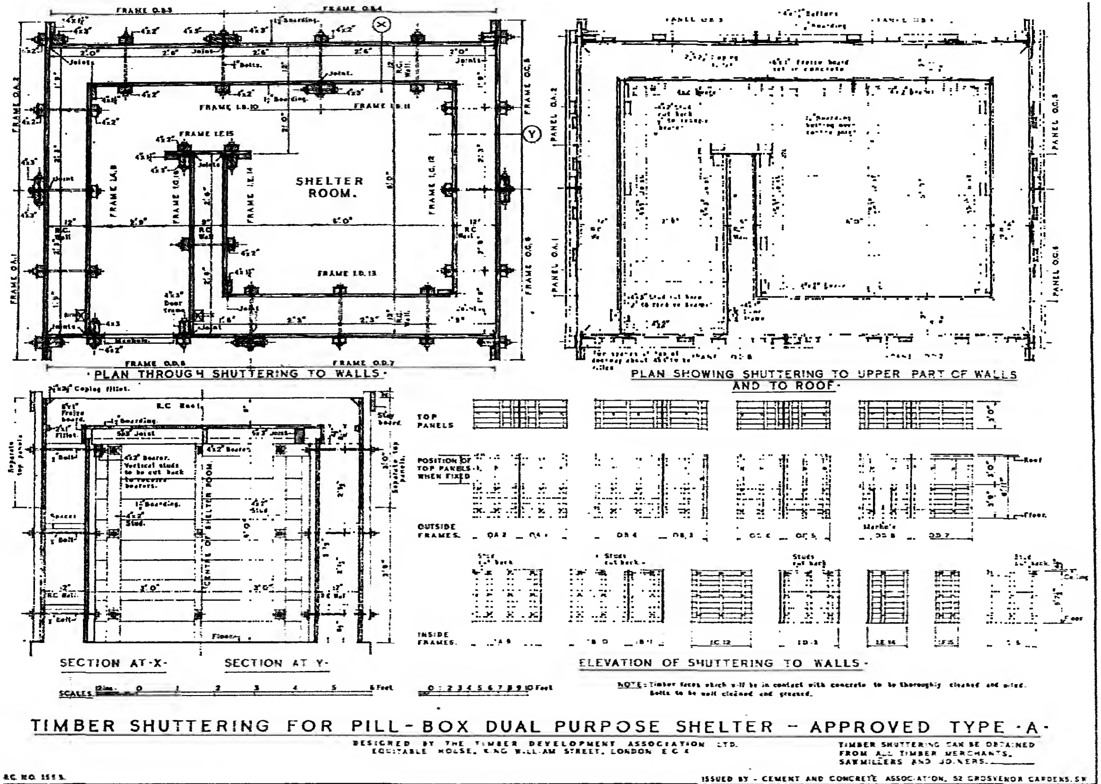
FIG. 133.—Sunk or partly sunk shelters based upon Government surface types.

(*Courtesy "The Builder."*)



PILL-BOX DUAL PURPOSE SHELTER TYPE A.
GAS CURTAIN
8'-6"
SIDE WALL FROM INSIDE
BACK WALL
11'-6"
PLAN
2'-0"
2'-9"
9"
6'-0"
8'-0"
12"
QUANTITIES
CONCRETE 12·3 CU.YD.
FORMWORK 61·5 SQ.YD.
REINFORCEMENT 200 LB.
BAR DETAILS
MILD STEEL 3/8" DIAM.
A 7'-3" 12" 8'-3" No. 10.
B 10'-6" 12" 11'-6" No. 5.
C 4'-3" 7'-0" 3" 11'-6" No. 5.
D 6'-6" No. 30.
ROOF E 4½" 7'-6" 4½" 8'-3" No. 7.
ROOF F 3" 11'-0" 3" 11'-6" No. 6.
2" × 1" GROOVE
FRONT WALL
12'-0"
18'-6"
3'-0"
DOUBLE SHELTER.
21'-6"
14'-6"
MULTIPLE SHELTER.
CEMENT AND CONCRETE ASSOCIATION 52 GROSVENOR GARDENS · S·W·1
DRG. NO. 1553.

FIG. 134.



No allowance is made for clearances

OUTSIDE WALL FRAMES

			Length	Height
Side A	Ref. OA1	Frame	4 ft. 8¼ in.	6 ft. 11 in.
		Top Panel	4 ft. 8¼ in.	3 ft. 0 in.
	„ OA2	Frame	4 ft. 8¼ in.	6 ft. 11 in.
		Top Panel	4 ft. 8¼ in.	3 ft. 0 in.
Side B	„ OB3	Frame	4 ft. 6 in.	6 ft. 11 in.
		Top Panel	4 ft. 6 in.	3 ft. 0 in.
	„ OB4	Frame	7 ft. 0 in.	6 ft. 11 in.
		Top Panel	7 ft. 0 in.	3 ft. 0 in.
Side C	„ OC5	Frame	4 ft. 8¼ in.	6 ft. 11 in.
		Top Panel	4 ft. 8¼ in.	3 ft. 0 in.
	„ OC6	Frame	4 ft. 8¼ in.	6 ft. 11 in.
		Top Panel	4 ft. 8¼ in.	3 ft. 0 in.
Side D	„ OD7	Frame	6 ft. 3 in.	6 ft. 11 in.
		Top Panel	6 ft. 3 in.	3 ft. 0 in.
	„ OD8	Frame	5 ft. 3 in.	6 ft. 11 in.
		Top Panel	5 ft. 3 in.	3 ft. 0 in.

INSIDE WALL FRAMES

Side A	Ref. I A9	Frame	7 ft. 0 in.	5 ft. 7½ in.
„ B	„ I B10	„	5 ft. 10½ in.	5 ft. 7½ in.
	„ I B11	„	3 ft. 6 in.	5 ft. 7½ in.
„ C	„ I C12	„	5 ft. 9½ in.	5 ft. 7½ in.
„ D	„ I D13	„	5 ft. 10½ in.	5 ft. 7½ in.
„ E	„ I E14	„	4 ft. 0 in.	5 ft. 7½ in.
„ F	„ I F15	„	2 ft. 1½ in.	5 ft. 7½ in.
„ G	„ I G16	„	5 ft. 0 in.	5 ft. 7½ in.

ROOF

Bearers	4 in. × 2 in.	2 lengths 4 ft. 3 in.
		1 length 5 ft. 4 in.
		1 length 2 ft. 6 in.
Joists	5 in. × 3 in.	3 lengths 5 ft. 8 in.
		2 lengths 6 ft. 9 in.
Boarding	1½ in. full	58½ sq. ft. net.

FRIEZE BOARD, 6 in. × 1 in. (built in).
1 length 6 ft. 5 in., 1 length 9 ft. 7 in., 2 lengths 6 ft. 1 in., 1 length 3 ft. 11 in., 1 length 0 ft. 9 in., 1 length 4 ft. 3 in.

DOVETAILED FILLET, 2in. × 1in., for wall channel.
2 lengths 11 ft. 6 in., 2 lengths 8 ft. 0 in.

TRIANGULAR FILLET, 2½ in. × 2½ in. for coping.
2 lengths 11 ft. 6 in., 2 lengths 8 ft. 0 in.

WALL SPACERS, 1½ in. × 1½ in.
39 lengths 1 ft. 0 in., 3 lengths 3 ft. 9 in.

BOLTS, ½ in. diam.
39 no. 9½ in. long, screwed 2½ in.
3 no. 17 in. „ „ 2½ in.
39 no. 22½ in. „ „ 4 in.
162 no. washers 2½ in. × 2½ in. × ⅛ in.

Fig. 135.

Sunk or Partly Sunk Shelters

Based upon the Government surface types, sunk or partly sunk shelters can be constructed generally as shown in Fig. 133.

Reinforced Concrete Pill-box Shelters

Fig. 134 shows details of pill-box dual-purpose shelter, Type A, designed by the Cement and Concrete Association.

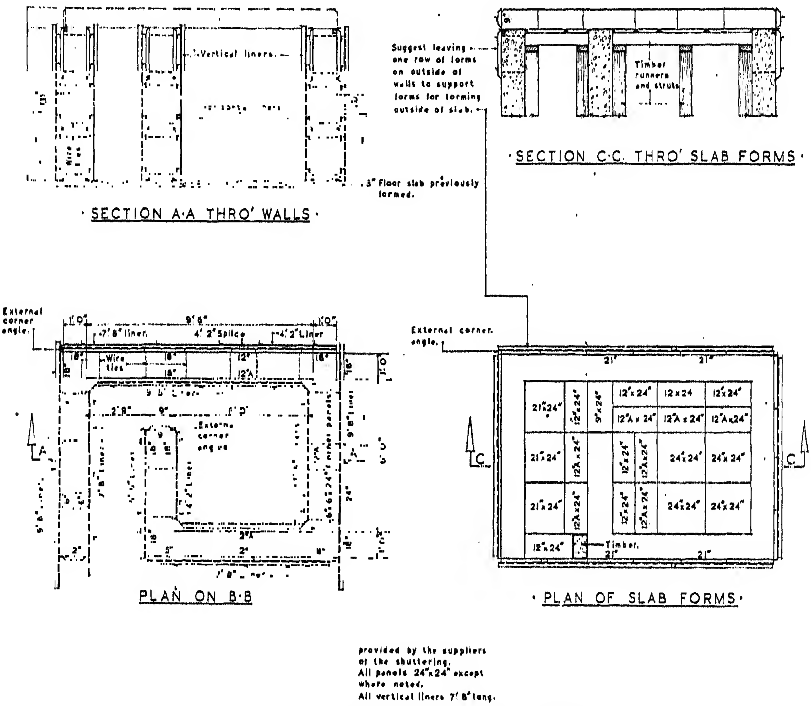


FIG. 136.—Steel forms for pill-box shelter.

Fig. 135 shows the timber shuttering required and Fig. 136 the alternative steel shuttering.

It is estimated that the complete cost of this unit shelter would be between £35 and £40 if the shelters were built in reasonable numbers, allowing for repeated use of shuttering.

An improved appearance and increased thermal insulation can be secured by the use of permanent timber shuttering, as shown in Figs. 137 and 138.

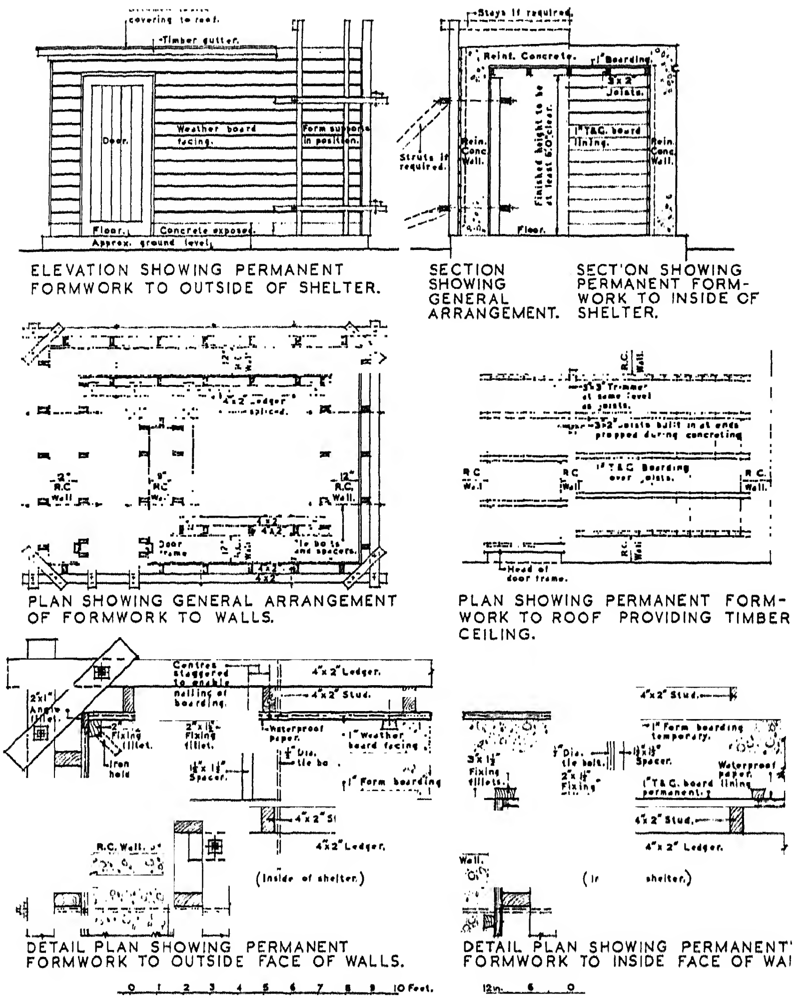


FIG. 137.—Permanent timber formwork for R.C. pill-box shelter.

Notes

Permanent timber formwork or shuttering can be applied to the outside of the structure as a facing, or to the inside as a lining.

It is not advisable to encase both sides of a concrete wall until the concrete has dried out, consequently permanent

formwork should only be applied on one side, either externally or internally.

The internal size of a shelter will be reduced by an internal lining. In setting out, this should be allowed for if necessary. This should be noted particularly in regard to the height.

Permanent shuttering applied externally may consist of a standard type of weather boarding 1 in. or more in thickness.

Internally the shuttering may consist of any convenient

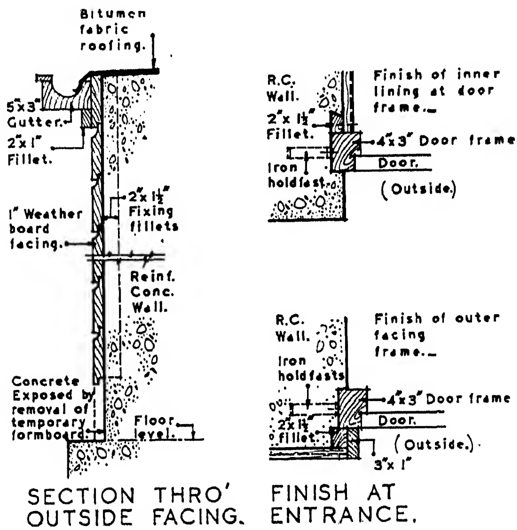


FIG. 138.—Details of permanent timber formwork for R.C. pill-box shelter.

type of boarding or plywood; 1 in. tongued, grooved and vee-jointed is shown.

A layer of waterproof building paper to be inserted immediately behind permanent shuttering.

Fixing fillets and timber embedded in concrete to be well treated with preservative, and similar treatment is recommended on the back of permanent shuttering.

Formwork to be constructed to give adequate support during concreting, and to enable supports and temporary timbers to be dismantled without damage to the permanent shuttering.

As an alternative to tie bolts as shown, strutting externally and internally may be adopted.

Timber spacers in walls to be removed as the work proceeds.

Faces of temporary formwork also tie bolts to be cleaned and oiled to facilitate removal.

Bolt holes to be plugged at completion.

Exposed surfaces of permanent shuttering can be painted or otherwise finished as desired.

Quantities

The quantities required are as below :—

Permanent Shuttering Applied as External Facing

Weatherboard facing (permanent)	1″ thick	243 sq. ft.
Shutter boarding (temporary)	1″ ,,	309 ,,
Studs and ledgers	4″ × 2″	563 lineal ft
Roof supports	5″ × 3″	48 ,,
Wall spacers	1½″ × 1½″	18 ,,
Fixing fillets, splayed	2″ × 1½″	91 ,,
,, ,, square	2″ × 1½″	39 ,,
Angle fillet, dressed	3″ × 1″	15 ,,
,, ,, ,,	2″ × 1″	26 ,,
Gutter, dressed	5″ × 3″	43 ,,
Capping, dressed	1½″ × ¾″	44 ,,
Bed fillet, dressed	2″ × 1″	41 ,,
Waterproof paper lining		30 sq. yd.
Bitumen roof covering		12 ,,
M.S. bolts and washers, ½″	2′ 9″ long	18 no.
	2′ 6″ ,,	2 ,,
	8″ ,,	8 ,,
	6″ ,,	44 ,,
M.S. holdfasts		12 ,,
Total timber.		92 cube ft.
Total bolts, etc.		89 lb.

Permanent Shuttering Applied as Internal Lining

Boarded lining (permanent)	1″ thick	286 sq. ft.
Shutter boarding (temporary)	1″ ,,	270 ,,
Splayed fillet to form channel in wall, dressed	2″ × 1″	39 lineal ft
Triangular fillet to form coping splay, dressed	2½″ × 2½″	39 ,,
Studs and ledgers	4″ × 2″	563 ,,
Roof supports, dressed	3″ × 3″	3 ,,
,, ,, ,,	3″ × 2″	47 ,,
Wall spacers	1½″ × 1½″	18 ,,
Fixing fillets, splayed	3″ × 1½″	50 ,,
,, ,, ,,	2″ × 1½″	125 ,,
,, ,, square	2″ × 1½″	13 ,,
Angle fillet, dressed	2″ × 1″	13 ,,
Waterproof paper lining		35 sq. yd.
M.S. bolts and washers, ½″	2′ 9″ long	18 no.
	2′ 6″ ,,	2 ,,
	8″ ,,	8 ,,
	6″ ,,	44 ,,
M.S. holdfasts		6 ,,
Total timber.		87 cube ft.
Total bolts, etc.		80 lb.

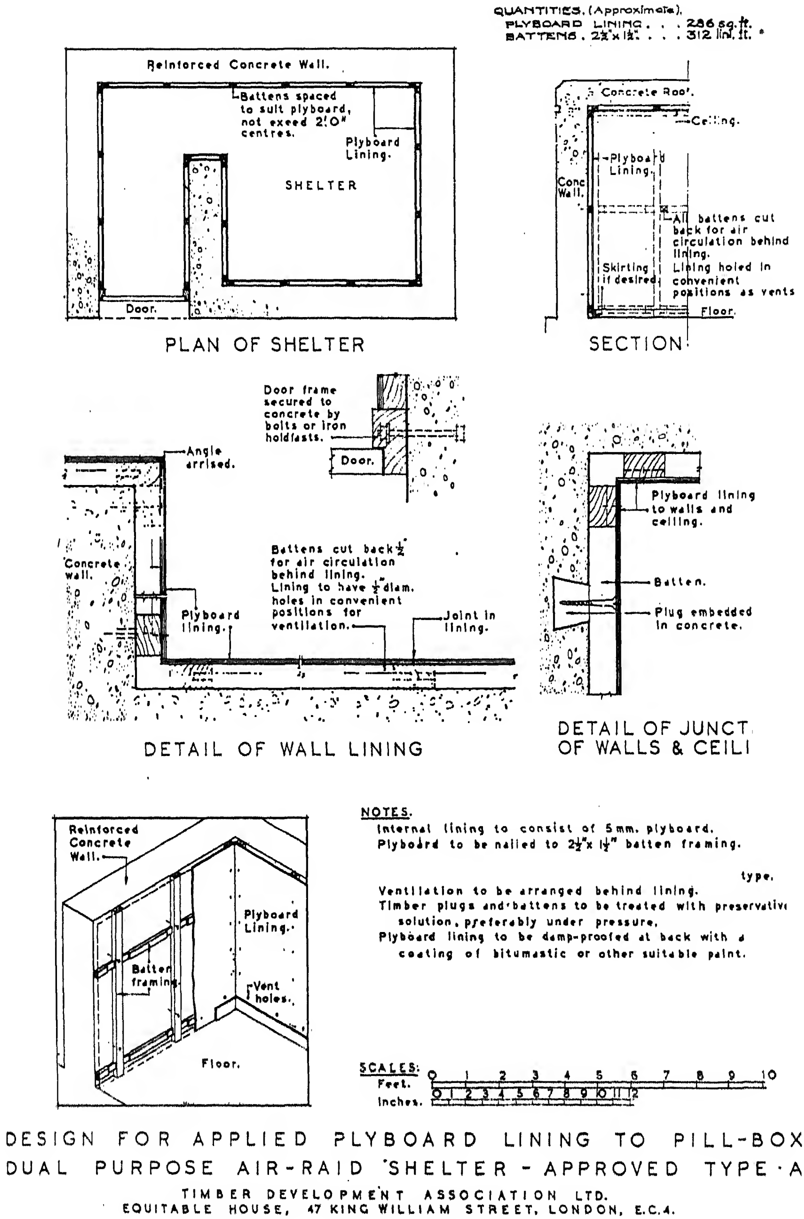

QUANTITIES. (Approximate).
PLYBOARD LINING . . . 286 sq. ft.
BATTENS . 2½"x 1½" . . . 312 lin. ft.
Reinforced Concrete Wall.
Battens spaced to suit plyboard, not exceed 2'.0" centres.
Plyboard Lining.
SHELTER
Door.
PLAN OF SHELTER
Concrete Roof.
Ceiling.
Plyboard Lining.
Conc Wall.
All battens cut back for air circulation behind lining.
Lining holed in convenient positions as vents
Skirting if desired.
Floor.
SECTION
Door frame secured to concrete by bolts or iron holdfasts.
Door.
Angle arrised.
Concrete wall.
Plyboard lining.
Battens cut back ½" for air circulation behind lining.
Lining to have ½" diam. holes in convenient positions for ventilation.
Joint in lining.
DETAIL OF WALL LINING
Plyboard lining to walls and ceiling.
Batten.
Plug embedded in concrete.
DETAIL OF JUNCT
OF WALLS & CEILI
Reinforced Concrete Wall.
Plyboard Lining.
Batten framing.
Vent holes.
Floor.
NOTES.
Internal lining to consist of 5mm. plyboard.
Plyboard to be nailed to 2½"x 1½" batten framing.
type.
Ventilation to be arranged behind lining.
Timber plugs and battens to be treated with preservative solution, preferably under pressure.
Plyboard lining to be damp-proofed at back with a coating of bitumastic or other suitable paint.
SCALES:
Feet. 0 1 2 3 4 5 6 7 8 9 10
Inches. 0 1 2 3 4 5 6 7 8 9 10 11 12
DESIGN FOR APPLIED PLYBOARD LINING TO PILL-BOX
DUAL PURPOSE AIR-RAID SHELTER - APPROVED TYPE A
TIMBER DEVELOPMENT ASSOCIATION LTD.
EQUITABLE HOUSE, 47 KING WILLIAM STREET, LONDON, E.C.4.

FIG. 139.

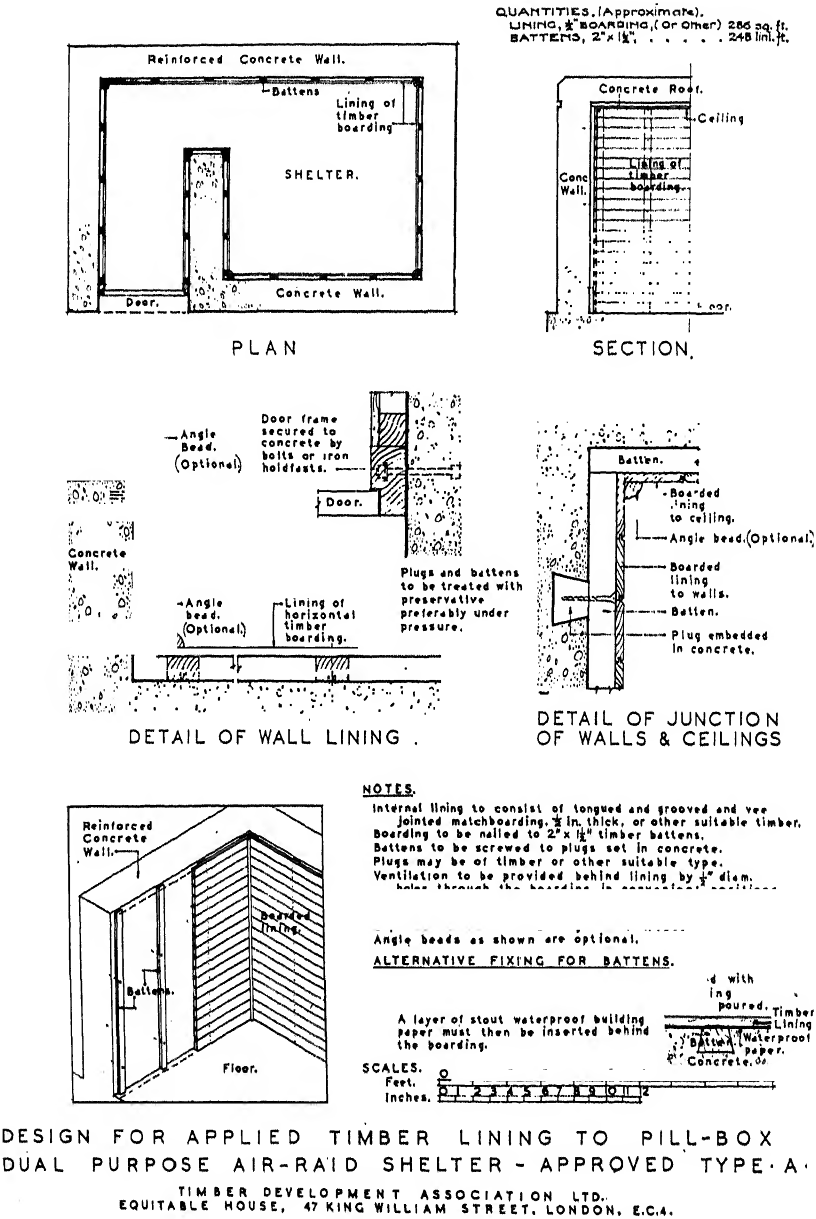
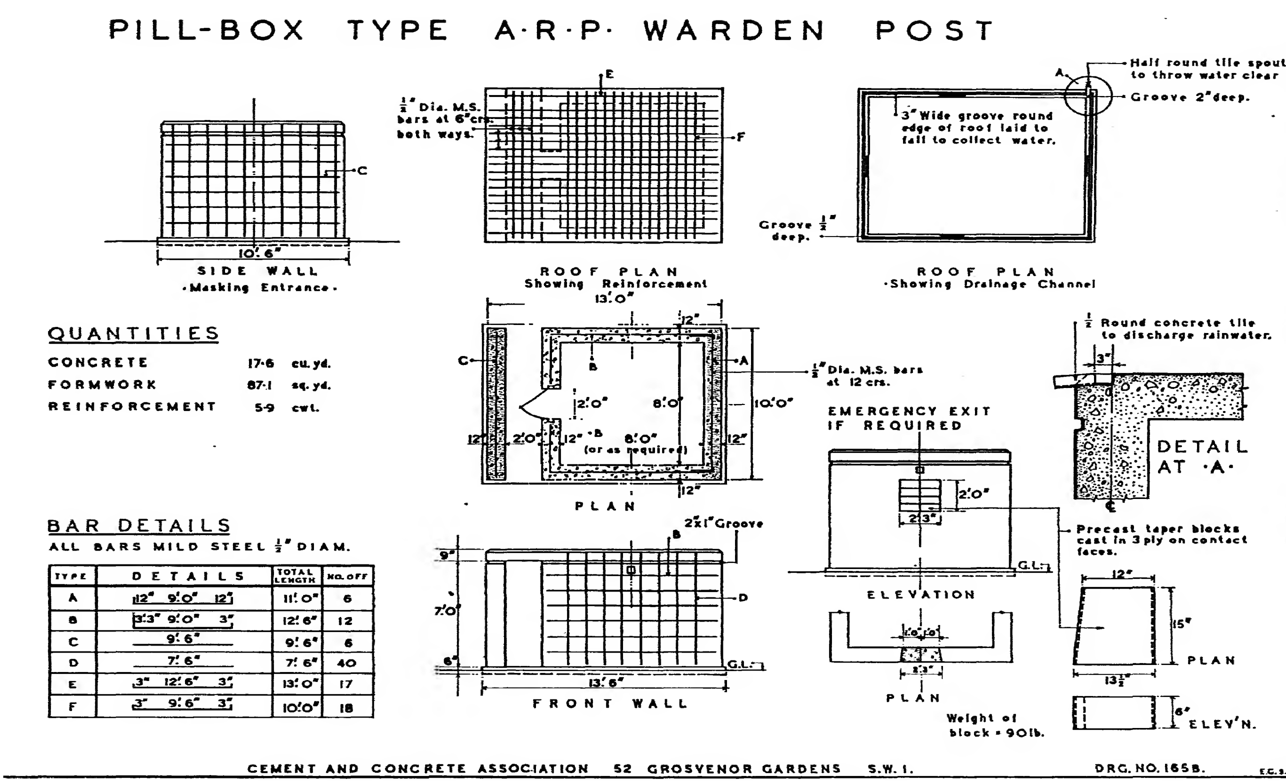

QUANTITIES. (Approximate).
LINING, ½" BOARDING, (Or Other) 286 sq. ft.
BATTENS, 2" x 1½". . . . . . . 248 lin. ft.
Reinforced Concrete Wall.
Battens
Lining of timber boarding
SHELTER.
Door.
Concrete Wall.
PLAN
Concrete Roof.
Ceiling
Conc Wall.
Lining of timber boarding.
SECTION.
Angle Bead. (Optional)
Door frame secured to concrete by bolts or iron holdfasts.
Door.
Concrete Wall.
Angle bead. (Optional.)
Lining of horizontal timber boarding.
Plugs and battens to be treated with preservative preferably under pressure.
DETAIL OF WALL LINING.
Batten.
Boarded lining to ceiling.
Angle bead. (Optional.)
Boarded lining to walls.
Batten.
Plug embedded in concrete.
DETAIL OF JUNCTION OF WALLS & CEILINGS
Reinforced Concrete Wall.
Boarded lining.
Battens.
Floor.
NOTES.
Internal lining to consist of tongued and grooved and vee jointed matchboarding, ½ in. thick, or other suitable timber.
Boarding to be nailed to 2" x 1½" timber battens.
Battens to be screwed to plugs set in concrete.
Plugs may be of timber or other suitable type.
Ventilation to be provided behind lining by ½" diam.
Angle beads as shown are optional.
ALTERNATIVE FIXING FOR BATTENS.
poured.
A layer of stout waterproof building paper must then be inserted behind the boarding.
Timber Lining
Batten.
Waterproof paper.
Concrete.
SCALES.
Feet.
Inches.
DESIGN FOR APPLIED TIMBER LINING TO PILL-BOX
DUAL PURPOSE AIR-RAID SHELTER - APPROVED TYPE A
TIMBER DEVELOPMENT ASSOCIATION LTD.
EQUITABLE HOUSE, 47 KING WILLIAM STREET, LONDON, E.C.4.

FIG. 140.


PILL-BOX TYPE A·R·P· WARDEN POST
10' 6"
SIDE WALL
·Masking Entrance·
C
E
F
½" Dia. M.S. bars at 6" crs. both ways.
ROOF PLAN
Showing Reinforcement
A
Half round tile spout to throw water clear
Groove 2" deep.
3" Wide groove round edge of roof laid to fall to collect water.
Groove ½" deep.
ROOF PLAN
·Showing Drainage Channel
QUANTITIES
CONCRETE 17·6 cu. yd.
FORMWORK 87·1 sq. yd.
REINFORCEMENT 5·9 cwt.
13' 0"
12"
B
2' 0"
8' 0"
10' 0"
12" 2' 0" 12" ·B 8' 0" (or as required) 12"
12"
PLAN
½" Dia. M.S. bars at 12 crs.
EMERGENCY EXIT IF REQUIRED
2' 0"
2' 3"
G.L.
ELEVATION
1' 0" 1' 0"
2' 3"
PLAN
Weight of block = 90lb.
½ Round concrete tile to discharge rainwater.
3"
DETAIL AT ·A·
Precast taper blocks cast in 3 ply on contact faces.
12"
15"
13½"
PLAN
6"
ELEV'N.
BAR DETAILS
ALL BARS MILD STEEL ½" DIAM.

TYPE	DETAILS	TOTAL LENGTH	NO. OFF
A	12" 9' 0" 12"	11' 0"	6
B	3' 3" 9' 0" 3"	12' 6"	12
C	9' 6"	9' 6"	6
D	7' 6"	7' 6"	40
E	3" 12' 6" 3"	13' 0"	17
F	3" 9' 6" 3"	10' 0"	18

2"x1" Groove
9"
7' 0"
6"
D
13' 6"
G.L.
FRONT WALL
CEMENT AND CONCRETE ASSOCIATION 52 GROSVENOR GARDENS S.W. 1.
DRG. NO. 165B.
E.C.S.

FIG. 141.

Linings in plywood or boarding are illustrated in Figs. 139 and 140, and these will be found to be self-explanatory.

Type B pill-box dual-purpose shelter is estimated to cost between £35 and £40 on the basis set out above.

Type C to similar details would cost £30 to £35, and

Pill-box type A.R.P. Wardens' post (Fig. 141) would cost about £50 to £60.

Buried Concrete Shelters

Figs. 142 and 143 show view and details of a buried rectangular concrete shelter designed by the Cement and Concrete Association.

The approximate quantities involved in the work of construction are as below:—

Length . . .	16′	6′ 6″
Capacity . . .	6 persons (or 16 with ventilation)	3 persons (or 6 with ventilation)
Excavation . .	60 cub. yd.	34 cub. yd.
Concrete . . .	12 ,,	7½ ,,
	Concrete Mix : 1 : 2½ : 4	
Bar reinforcement .	4½ cwt.	2 cwt.
Mesh reinforcement .	64 sq. yd.	41 sq. yd.

Circular Type of Buried Concrete Shelters

An excellent type of circular concrete shelter of the large man-hole form is sold by Messrs. Universal Floors Ltd. It is illustrated in Figs. 144–147 inc.

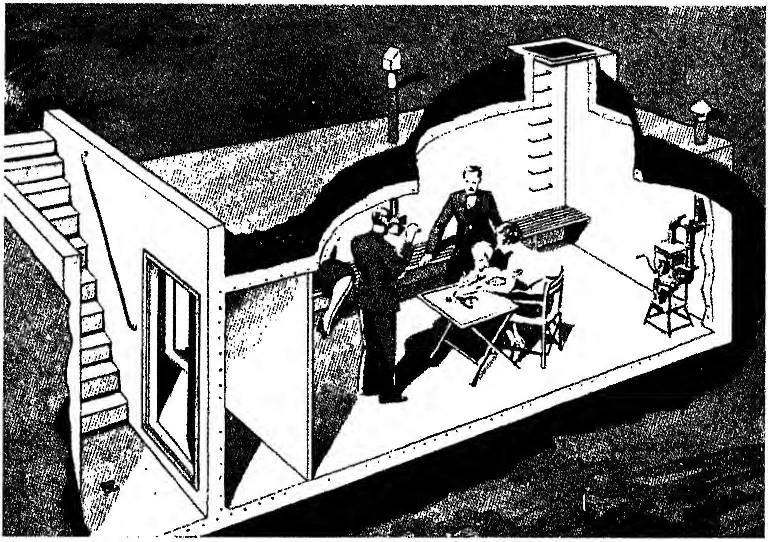
The particulars and prices are as follows :—

Type A (see Fig. 145) is the "Ventilated" type. It cannot be made gas-proof, and during a gas attack gas masks would have to be worn. It does, however, provide ample protection from bomb splinters and flying *débris*. It is essentially as shown in Fig. 145.

To accommodate seven persons.

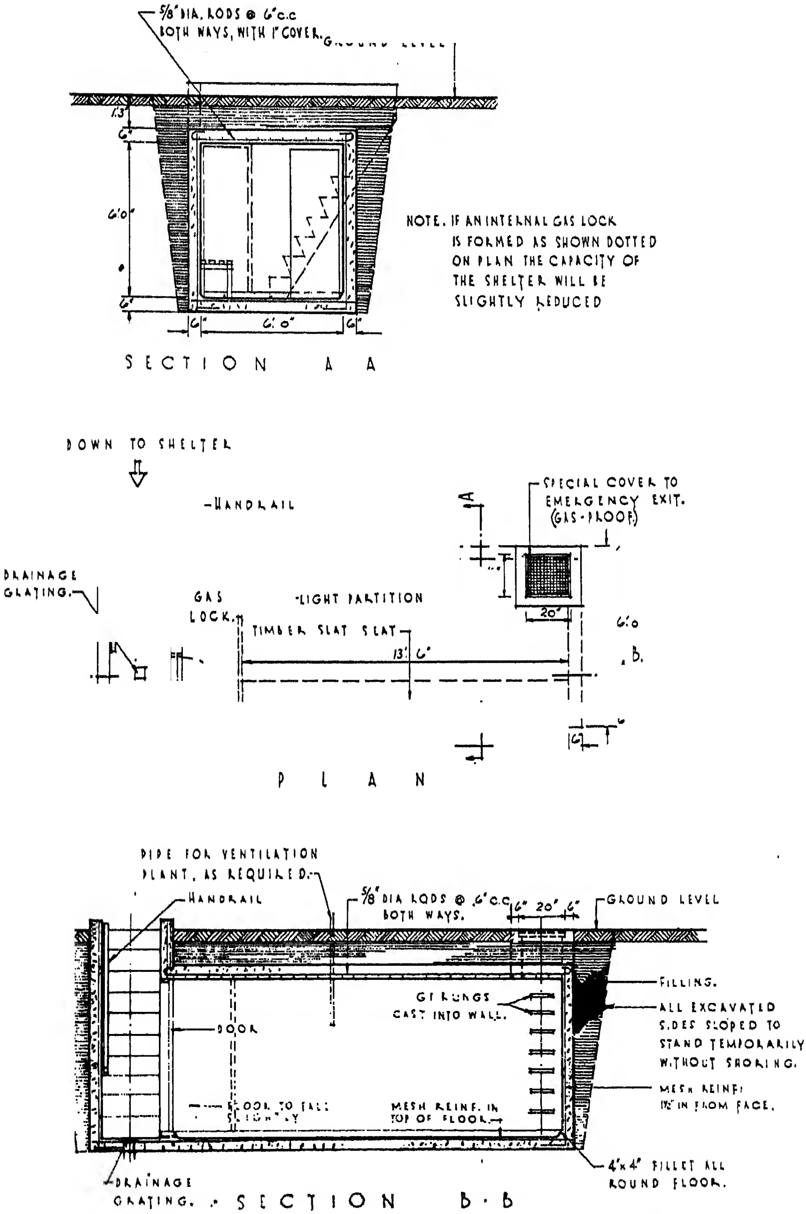
	£	s.	d.
Cost, complete as diagram, materials supplied only	32	0	0
Approximate cost, installed (according to site conditions)	46	0	0

Type B (see Fig. 145). This is similar to Type A, but with the addition of arrangements for the installation of an air conditioning plant, as shown in Fig. 146. This type is gas-proof.



(*Courtesy C. & C.A.*)

FIG. 142.—Cut-away view of buried rectangular concrete shelter.



(*Courtesy C. & C. A.*)

FIG. 143.—Details of buried R.C. shelter.

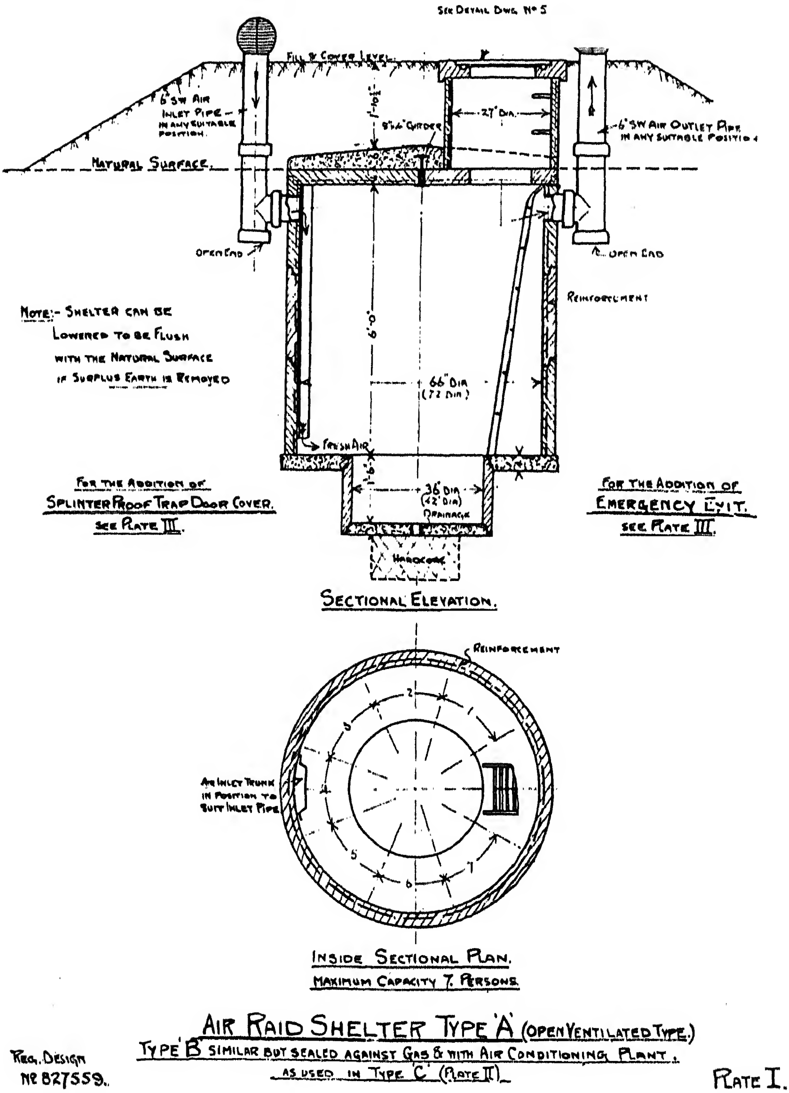


FIG. 145.

To accommodate seven persons.	£	s.	d.
Cost, complete with air conditioning plant, supplied only	48	0	0
Approximate cost, all as above, installed (according to site conditions)	63	0	0

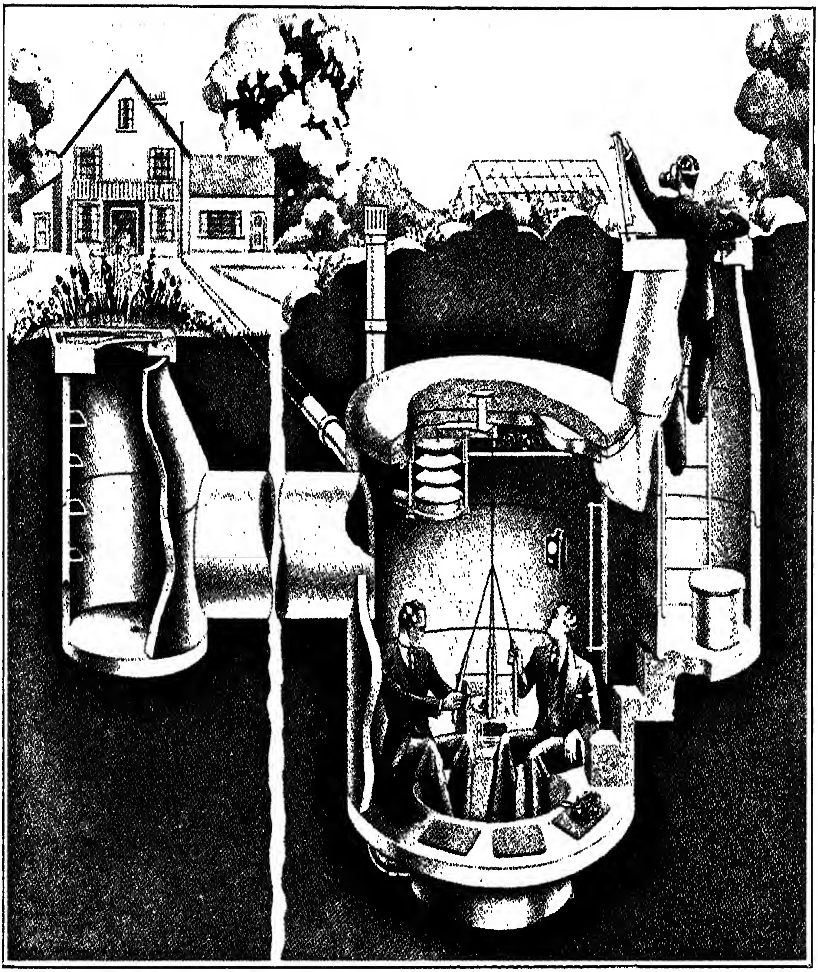


FIG. 144.—Cut-away view of man-hole type of domestic shelter.

[To face page 316.

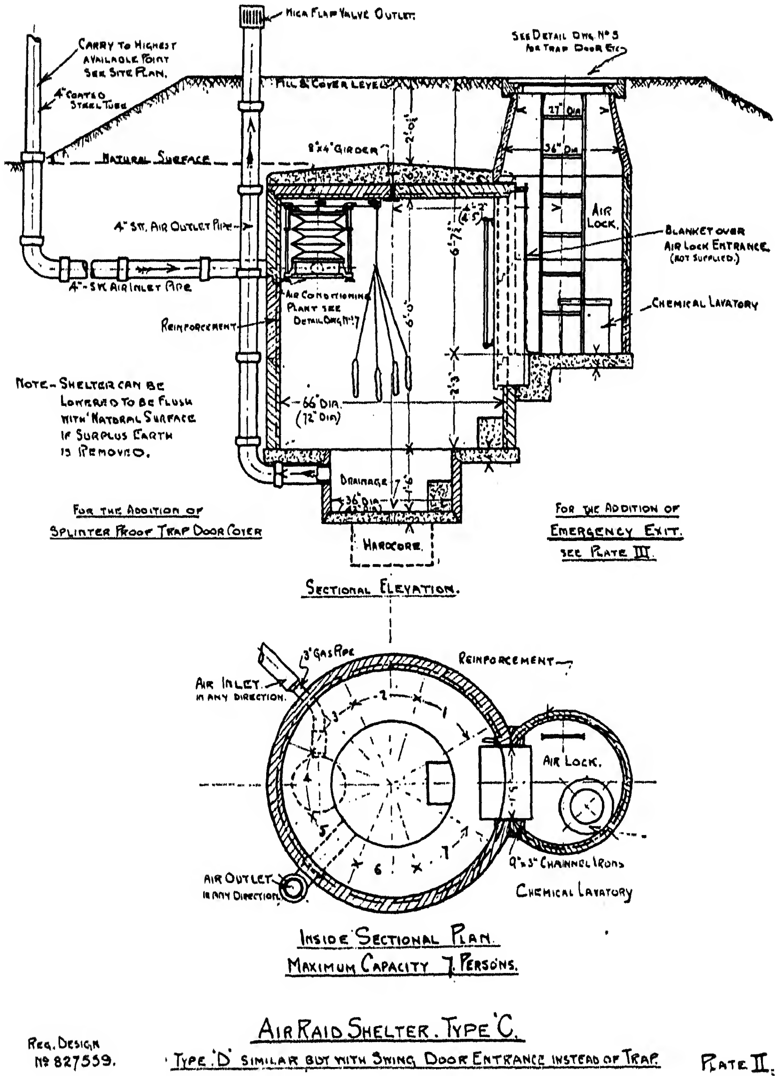


FIG. 146.

Type C (see Fig. 146). In this design the main chamber is similar in construction to Type B, including the air conditioning plant, but with the addition of an air-lock and chemical lavatory.

The air-lock gives additional security against gas, and also

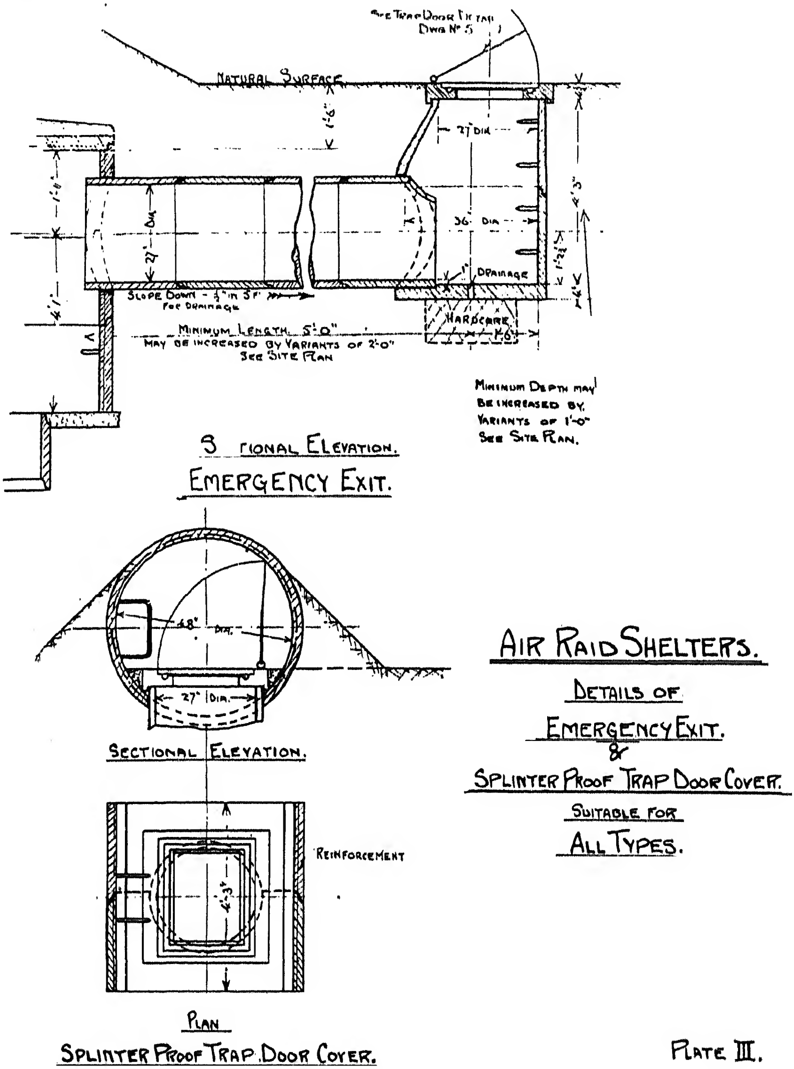


FIG. 147.

provides an easier means of entrance. It also provides screened accommodation for the chemical lavatory.

To accommodate seven persons.

	£	s.	d.
Cost, complete, with air conditioning plant and chemical lavatory. Materials supplied only .	59	0	0
Approximate cost, all as above, installed (according to site conditions)	76	0	0

Type D (see Fig. 147). This is exactly as for Type C, but with the addition of a side door entrance to the air-lock in place of the trapdoor.

To accommodate seven persons.	£	s.	d.
Cost, complete, with air conditioning plant and chemical lavatory. Materials supplied only .	70	0	0
Approximate cost, all as above, installed (according to site conditions)	90	0	0

Emergency Exit. Minimum length, see Fig. 147. This is suitable for all types of shelter, and is strongly recommended by the Home Office. It provides an alternative means of escape should the ordinary exit become damaged or buried by wreckage.

	£	s.	d.
Cost, materials supplied only . . .	11	0	0
Approximate cost, installed (according to site conditions)	15	0	0
Extra length per foot.			
Cost, materials supplied only	0	8	0
Approximate cost, installed	0	15	0

Shrapnel Screen for Trapdoor. This screen is suitable for Types A, B and C only. It provides additional protection to the entry trapdoor, screening it from spent shrapnel and other flying fragments from bombs and anti-aircraft fire.

	£	s.	d.
Cost, materials supplied only	6	10	0
Approximate cost, installed	8	5	0

Draining Pump for Wet Ground. In wet ground the drainage soakaway would be useless and it would be necessary to pump out any accumulated condensation or other dampness that may have collected. This pump is suitable for all types.

	£	s.	d.
Cost, materials supplied only	3	15	0
Approximate cost, installed	5	0	0

Internal Door (in lieu of Blanket). Suitable for Types B and C only.

	£	s.	d.
Cost, materials supplied only	1	10	0
Approximate cost, installed	2	0	0

Shelves. Suitable for all types.

		£	s.	d.
Cost, materials supplied only . .	each	0	5	0
Approximate cost, installed . .	,,	0	9	0

Fig. 148 shows an improved type of family shelter, giving a very high degree of protection. Attention is directed to the fact that the shelter proper is contained within a 6 ft. diameter reinforced concrete tube sunk vertically in the ground with a

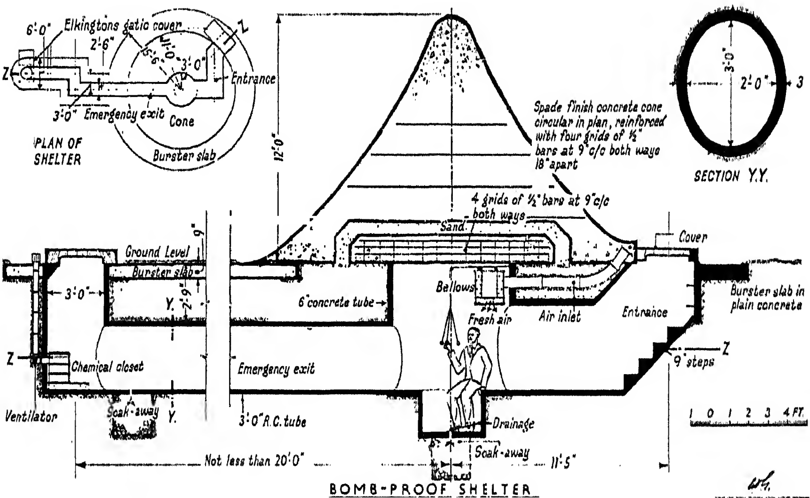


FIG. 148.—Bomb-proof family shelter.

smaller tube in the bottom to give the necessary leg space. Entrance and exit is through a tunnel of egg section, and the roof is in the form of reinforced concrete carried to any desired thickness. A concussion layer of sand or aerated concrete is then spread over the roof of the shelter, and the reinforced concrete cone, which acts as a bomb deflector and detonator, is constructed thereon. The entrance, as shown on this drawing, is closer to the shelter than would be desirable, but the general arrangement, as shown in the small plan, should wherever possible be adhered to provided the entrance is kept further from the centre of the shelter.

Steel Shelters

The pressed steel " Elephant " type of steel shelter afforded by far the most secure " above ground " protection to our armies in France in the Great War, and Messrs. Joseph Westwood & Co. Ltd. are still producing this type of shelter in curved pressed steel troughing $\frac{1}{8}$ in. thick.

There are three models—5 ft. 6 in., 7 ft. 6 in. and 9 ft. 6 in. wide—available at prices of £1 10*s*., £2 and £2 2*s*. 6*d*. per foot run respectively.

The household shelter made of the same material is produced to the Government standard dimensions—6 ft. 6 in. high, 4 ft. 6 in. wide and 6 ft. long. In it six to eight adults and children can be accommodated.

It should be sunk to a depth of 2 ft. and surrounded by sand-bags or earth to a thickness of 2 ft. 6 in.

The cost, with pressed steel troughing back, is £13 f.o.r. London. Extra lengths 2 ft. wide at £3.

Notes on the Erection and Sinking of the Galvanised Corrugated Steel Shelter approved by the Home Office (the Anderson Shelter)

Fig. 149 shows the individual parts of this steel shelter, which, it will be seen, is of an arched type. The internal dimensions are 6 ft. 6 in. long, 4 ft. 6 in. wide and 6 ft. high, and when erected in a pit it is the intention that earth should be heaped over the roof of the shelter. The shelter is intended to be splinter-proof and resistant to blast, whilst its resistance to direct impact of small bombs may be considerably increased if the corrugated iron is first covered with a layer of good concrete before the earth is applied. This construction will also prolong the life of the shelter and increase its resistance to the penetration of moisture. The shelter should be located as far as convenient away from any buildings to be clear of the possible effects of demolition of such buildings. The best distance to adopt is half the height of the building, but it should not be less than 6 ft. If, however, the shelter is situated more than 15 ft. from the building, the entrance to it should be protected with an earthen or other type of wall affording splinter protection to the entrance. Before excavating

for the shelter it is advisable to ascertain from the local authorities or from existing records the run of the drains and the levels of the water mains in the vicinity in order to ensure that the site is reasonably free from the danger of flooding.

Fig. 150 shows the excavation required. If this is made 7 ft. 6 in. long and 6 ft. wide and 3 to 4 ft. deep, there will be plenty of room in the excavation to erect the component

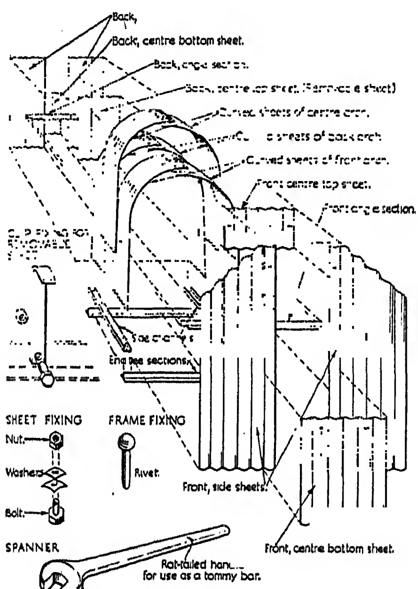


FIG. 149.—The individual parts of the Anderson steel shelter.

parts. The minimum depth of the excavation should be 2 ft. below normal ground level. In erecting the shelter a frame of steelwork is arranged at the bottom of the excavation, the two side channels resting upon the end tee, as shown in Fig. 150. The frames should be carefully tested for squareness, and when finally located the rivets provided should be driven through the hole in the channel and through that in the tee down into the ground itself.

It is important to ensure that the whole of the bottom frame is thoroughly protected with bituminous or other paint before the rest of the shelter is erected upon it.

Two men now proceed to erect the six curved corrugated sheets, bolting them through at the top, generally as shown

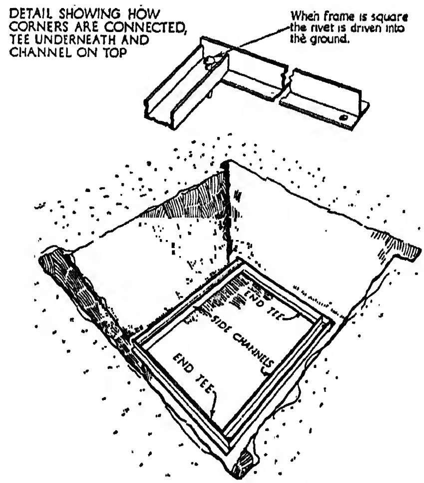


FIG. 150.—The frame arranged in the bottom of the hole.

at Fig. 151. The end sets of curved sheets are first erected and the middle sets then placed over them, as indicated in

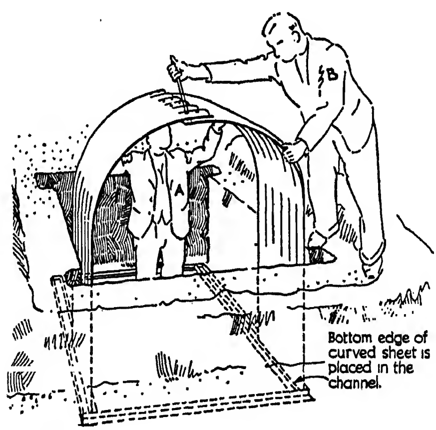


FIG. 151.—Erecting the back Arch. A. Supports curved sheets. B. Levers slots into line with bar.

Fig. 149. A liberal application of bituminous paint should be used on all overlapping sheets and on bolts, nuts and washers used in fixing them, especially along the soffit of the arches,

in order to ensure that the joints may be reasonably water-tight.

The back end is next fitted, as shown in Figs. 152 and 153.

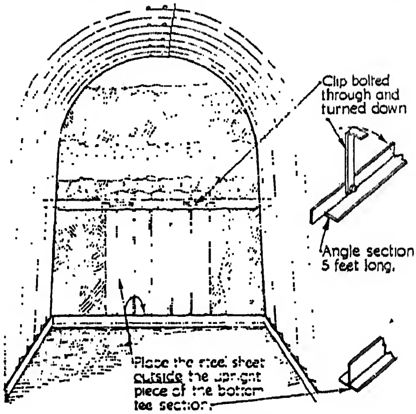


FIG. 152.—Method of fixing end sheets into position.

One of the angle sections is bolted to one of the 3 ft. sheets, the same bolt being used to fix the two clips on the inside.

The two 6 ft. corrugated sheets are then placed one on each side of the central sheet with an overlap of one corrugation,

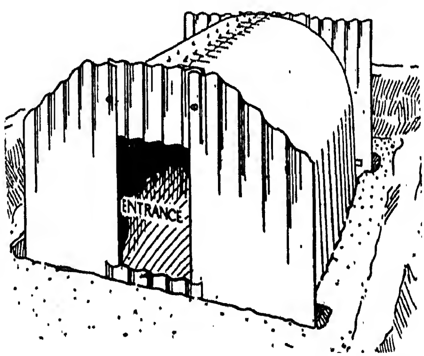


FIG. 153.—The shelter complete ready for the earth cover.

and the end is completed by the fixing of the sheet 3 ft. 3½ in. long, which is pushed from the inside until it just projects above the arch and rests upon the clips. When the clips are turned upwards this sheet will be held firmly in place. It performs the function of an emergency exit, as it can be

removed at any time by reversing the operation described above, namely, bending the clips sideways and downwards and removing the sheet inwards into the shelter.

The front of the shelter is similarly erected and the structure is now ready to be covered in earth. It is important that the material filled in between the metal and the sides of the excavation be thoroughly well tamped, as this holds the end sheeting of the shelter in place. When the earth is heaped over the top of the shelter the finished appearance is generally

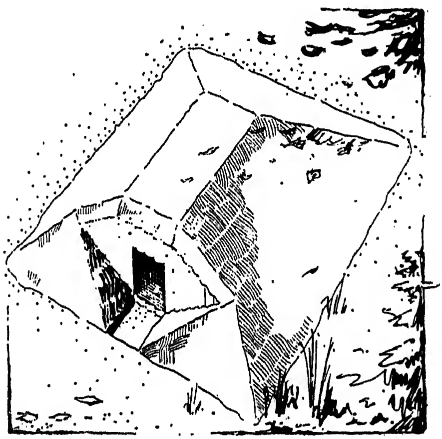


FIG. 154.—The shelter complete with earth cover.

as shown in Fig. 154. The floor may be finished in ashes, broken rubble, duck boards or concrete as desired, but it is important to scrape the earth away from the entrance to drain off the water.

It is desirable to keep a spanner and a spade permanently in the shelter for emergency use in the event of the entrance or exit being blocked by *débris*.

Permanent Shelters in Houses

The various "domestic" splinter-proof and gas-proof shelters hitherto considered have been of the emergency type and excepting only the underground shelters or covered trenches camouflaged as rock gardens, they are quite conspicuous.

For a small extra initial expenditure a built-in air raid

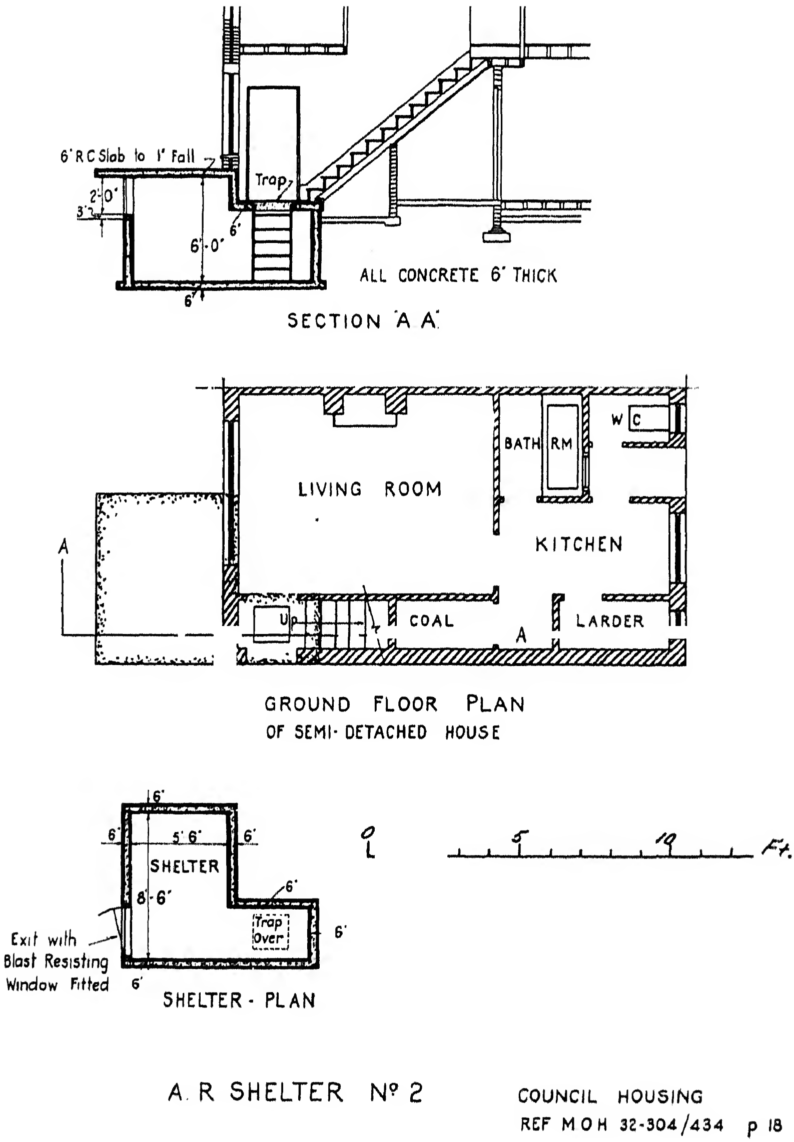


FIG. 155.—Permanent R.C. shelter under the smaller house.

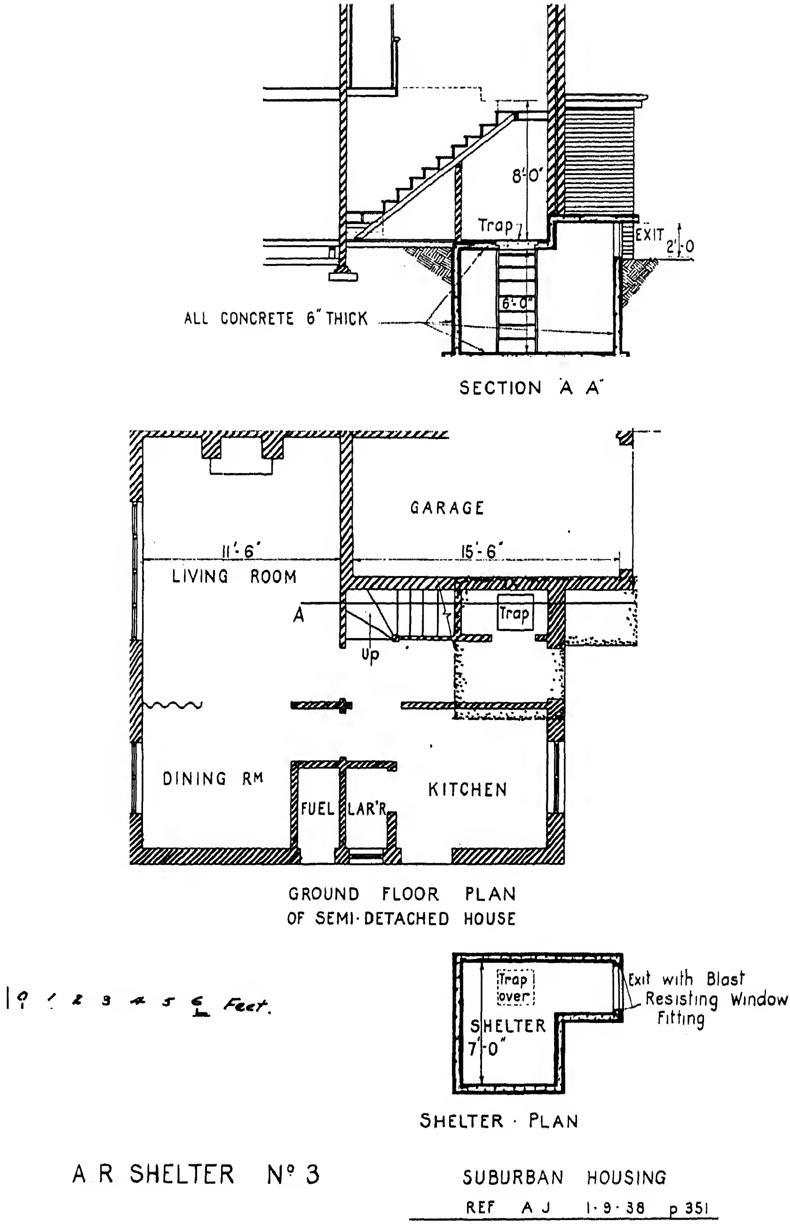


Fig. 156.—Permanent R.C. shelter under the smaller house.

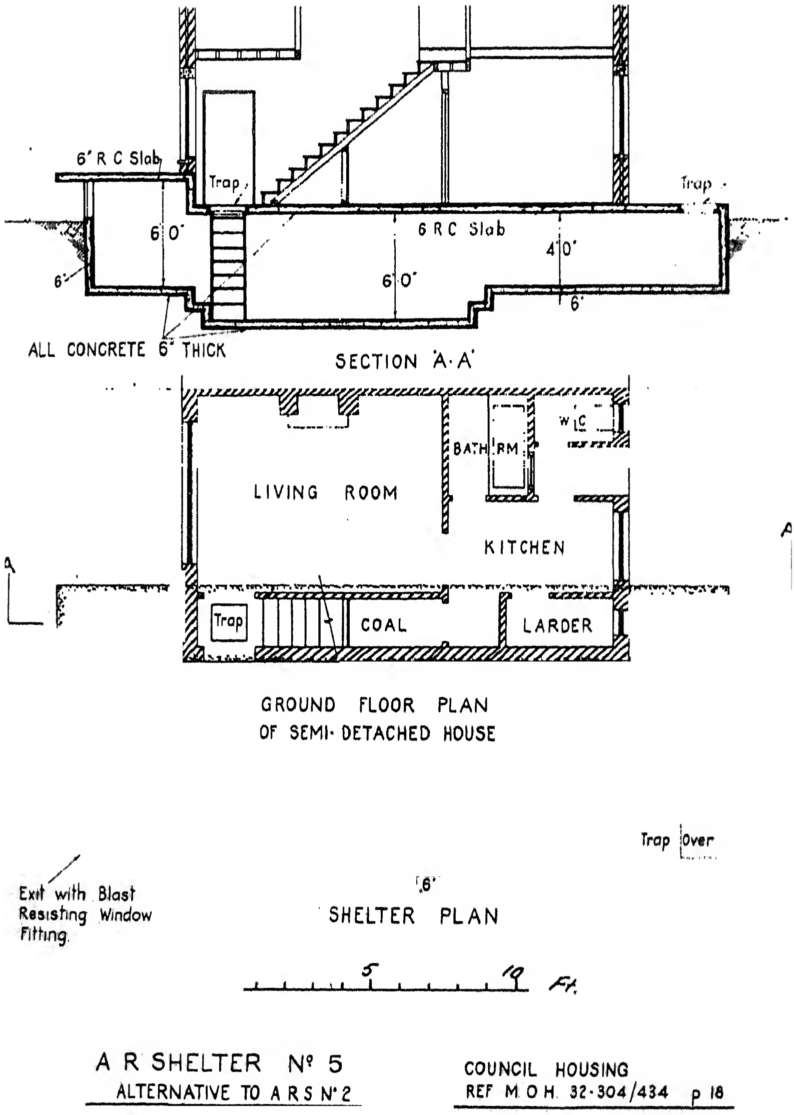
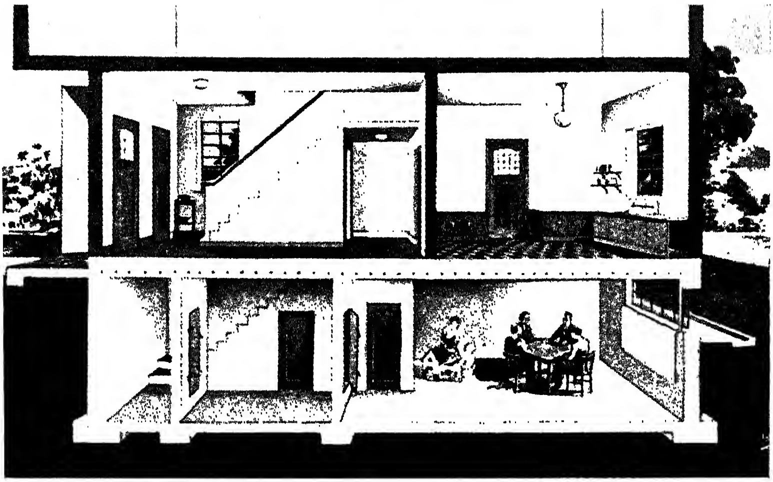


FIG. 157.—Permanent R.C. shelter under the smaller house.
(Courtesy C. & C. A.)



(*Courtesy C. & C. A.*)

FIG. 158.—Reinforced concrete basement to house giving class 5 protection.

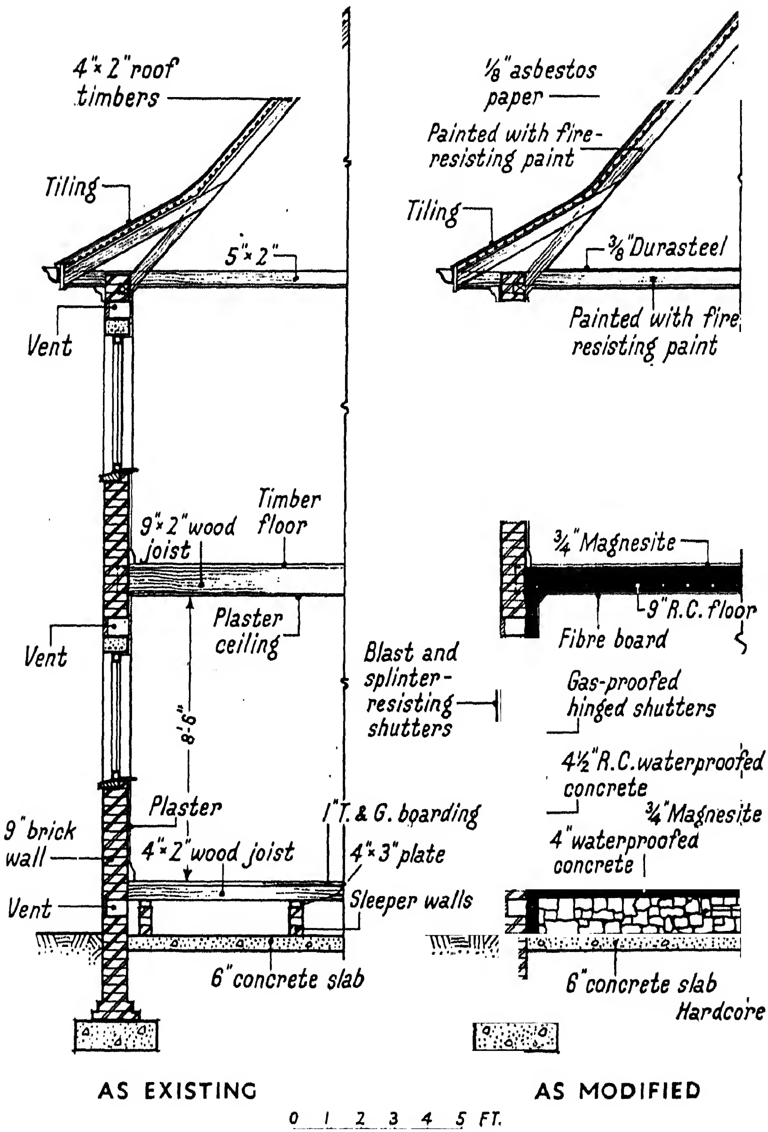


FIG. 159.—Permanent shelters in houses.

TABLE LXXXVII
STEEL TUBULAR SHELTERS

No.	Length	Internal diameter.		Capacity Sealed Shelter.		Capacity Ventilated Shelter.		Prices.					
				Normal (6 hrs.).	Crush (2 hrs.).	Normal (6 hrs.).	Crush (2 hrs.).	Installed complete.			Materials only.		
	ft.	ft.	in.					£	s.	d.	£	s.	d.
S.T.S. 1 .	30	4	6	6	14	18	32	103	2	0	95	3	0
S.T.S. 2 .	62	4	6	12	28	38	66	161	5	0	146	8	0
S.T.S. 3 .	106	4	6	20	50	66	113	241	3	0	216	18	0
S.T.S. 4 .	158	4	6	30	74	98	169	335	13	0	300	4	0
S.T.S. 5 .	210	4	6	40	100	131	225	430	2	0	383	10	0
S.T.S. 6 .	266	4	6	50	126	166	285	521	17	0	473	5	0
S.T.S. 7 .	26	5	0	6	14	17	29	103	8	0	95	11	0
S.T.S. 8 .	58	5	0	12	30	38	66	167	17	0	152	13	0
S.T.S. 9 .	94	5	0	20	50	62	107	240	7	0	216	18	0
S.T.S. 10 .	142	5	0	30	74	94	162	337	0	0	302	11	0
S.T.S. 11 .	190	5	0	40	100	126	217	433	13	0	388	4	0
S.T.S. 12 .	238	5	0	50	126	158	272	530	6	0	473	17	0
S.T.S. 13 .	22	6	0	6	14	17	28	109	12	0	98	11	0
S.T.S. 14 .	50	6	0	12	32	39	67	180	15	0	158	8	0
S.T.S. 15 .	82	6	0	20	52	65	110	262	2	0	226	16	0
S.T.S. 16 .	118	6	0	30	74	93	160	353	12	0	303	15	0
S.T.S. 17 .	162	6	0	40	102	128	220	465	8	0	397	16	0
S.T.S. 18 .	202	6	0	50	128	160	274	567	2	0	483	6	0

shelter can be constructed as an integral part of a new house. The shelter may take the form of a basement, a store-room, or a gas- and splinter-proof kitchen.

Figs. 155–157 show how such shelters can be built under the smaller house, and Fig. 158 a complete basement giving Class 5 protection.

Since the war the number of owner-occupiers of houses in this country has increased by more than two millions, and it is estimated that a very high proportion of them would be willing to have a room permanently gas-proofed and splinter-proofed provided the finished work could remain inconspicuous, the additional work to the property could be wholly derated and building society loans could be secured to meet the major part of the expense.

To meet this very real demand, the author has given consideration to the problem presented by the average villa and has prepared plans and estimates of the work involved. Modern houses of the smaller type seldom have basements but Fig. 159 illustrates the proposals which involve the following:—

1. Fireproofing.

(a) The laying of a continuous covering of $\frac{3}{8}$ in. Durasteel all over the loft floor.

(b) The painting of all roof timbers with fire-resisting paint.

(c) The covering of the underside of the roof with $\frac{1}{8}$ in. asbestos paper.

Note.—The whole of this work remains unseen and does not interfere with the peace time use of the loft as may be desired.

2. Blast and Splinter-proofing.

(a) The taking up of the ground floor of the selected room assumed to be 12 × 12 ft. and the laying of waterproofed concrete over the ground concrete to bring the floor up solid for a $\frac{3}{4}$ in. magnesite or similar jointless finish.

(b) The thickening of external walls to 13 in. and internal walls to 9 in. by an appropriate addition of densified reinforced concrete on the inside—plaster being removed and brickwork hacked for the purpose of securing a good bond.

(*c*) The removal of the ceiling and first floor over the selected room, replacing this with a solid reinforced concrete floor 9 in. thick, laid on insulating fibre board as permanent shuttering and ceiling finish and finished on top with magnesite or other approved jointless floor.

(*d*) The provision of blast and spinter-resisting shutters to windows generally as Fig. 77.

(*e*) The provision of gas-proof hinged shutters to interior of windows generally as shown in Fig. 77.

(*f*) The provision of gas-proof doors—in lieu of those existing—generally as shown in Fig. 26.

(*g*) The provision of a permanent but removable fireplace cover with ventilating and air filtering attachment (stored for emergency use).

Note.—All items, except the last-mentioned, could be carried out at once and would not interfere with the normal use of the room.

3. GAS-PROOFING.

(*a*) The provision of rubber gaskets on all sliding or closing edges of windows as additional gas stop.

(*b*) The finishing of all new wall surfaces in Gypsum plaster finished with a gas-proof skin of enamel to owner's selection.

(*c*) Sealing all vents not already covered with new work.

Note.—The gas-proofing can be executed at once without in any way interfering with the appearance or normal use of the room.

The above described works for a room 12 ft. × 12 ft. × 8 ft. 6 in. high are estimated to cost £100, but if the above specification were adopted for a "shelter" room in a new house the cost would not exceed £25, additional to the cost of the building if carried out to the normal specification.

Each case should, of course, be dealt with on its own merits and architect's plans prepared and deposited for approval.

Normally, a "conversion" would take four weeks.

The room as described would give reasonable protection from blast, splinters and gas and would be suitable for "sealed in" occupation by 16 persons for six hours or

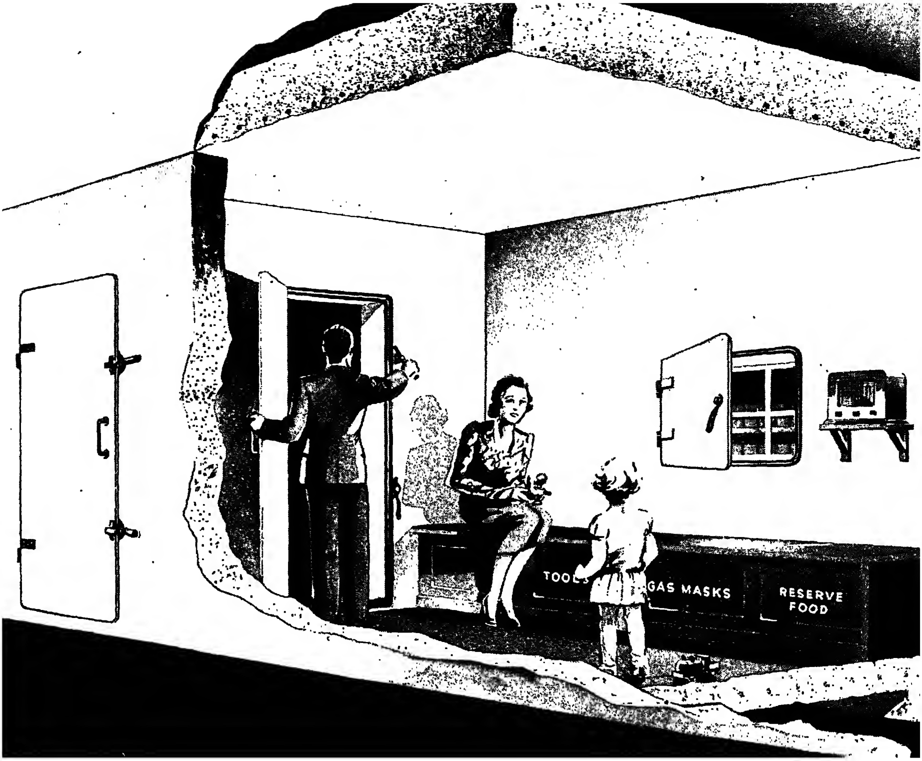


FIG. 160.—Permanent air raid shelters in houses.

continuous occupation by 24 persons with filter and ventilator working.

A cheaper alternative is in the production of a small family lean-to shelter in reinforced concrete generally, as shown in Fig. 125, and estimated to cost no more than £55.

Splinter-proof shelters of various designs can also be incorporated under the gardens behind semi-detached houses, arranged to be shared by the occupants of both homes.

Shelters of the reinforced concrete tube design can be arranged in this way so that the additional rent required to cover the cost would vary between 8*d*. and 1*s*. per week.

Trenches

By the mere expenditure of a few shillings per head on sand-bags, corrugated iron or similar scrap material, a householder can provide splinter-proof protection for his family in covered trenches in the garden camouflaged as a rock garden. Details of construction of trenches and methods of covering them are given in the section which follows.

CHAPTER IX

TRENCHES

Generally

The digging of trenches and the provision of head cover over them is perhaps the easiest way to provide for all kinds of protection, except against direct hit by high explosive.

Various sections of trench shelters are shown in Figs. 161 and 163, from which it will be seen that a minimum safe depth below ground is of the order of 6 ft.

Careful attention must be paid to waterproofing, and the selection of a suitably drained site is of first importance.

Garden Trenches

Fig. 164 shows sketch of a type of garden trench shelter recommended by the Home Office. It is intended for the accommodation of six persons and is 16 ft. long, 3 ft. 6 in. wide at the bottom and 4 ft. 6 in. wide at the top.

It is divided into three sections—a shelter 10 ft. long, a 3 ft. length with a sloping gas curtain on a wooden frame, and a 3 ft. length at the ladder entrance.

The shelter affords temporary protection only unless lined with more permanent materials, such as Type W (Figs. 177 and 178).

The constructional details are shown in Fig. 178, and the method of installation in Fig. 177. The only tools required for Type W are a pick, spade, and (for mixing the floor concrete, etc.) a shovel and bucket. If the seat, gas screen frame, etc., are to be home-made, a saw, hammer and nails will be needed.

Procedure

1. Mark out the ground 4 ft. 6 in. wide by 15 ft. 6 in. long. Excavate as shown in Fig. 177. As the excavation proceeds insert temporary wooden struts from side to side, bearing on pieces of plank, to prevent risk of the sides slipping in. Construct sump in the floor below the entrance.

If water is struck and it is impossible to excavate to the

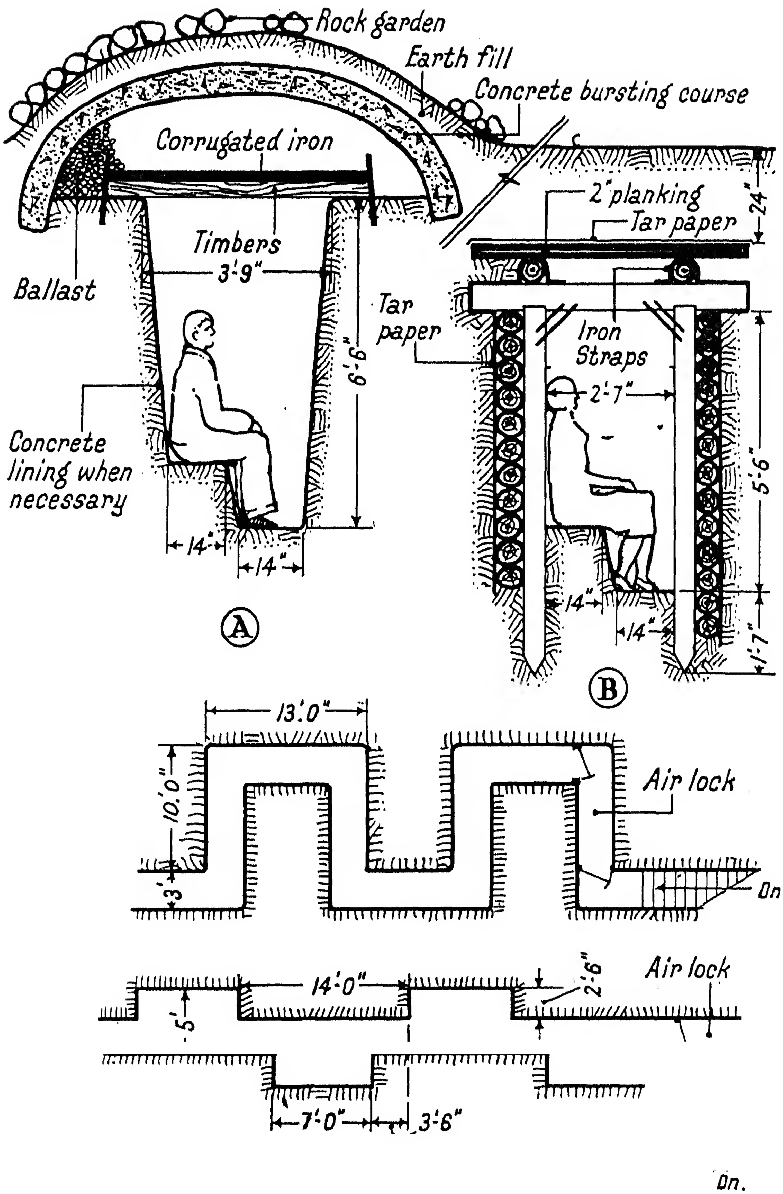


FIG. 161.—Trenches on dry sites.

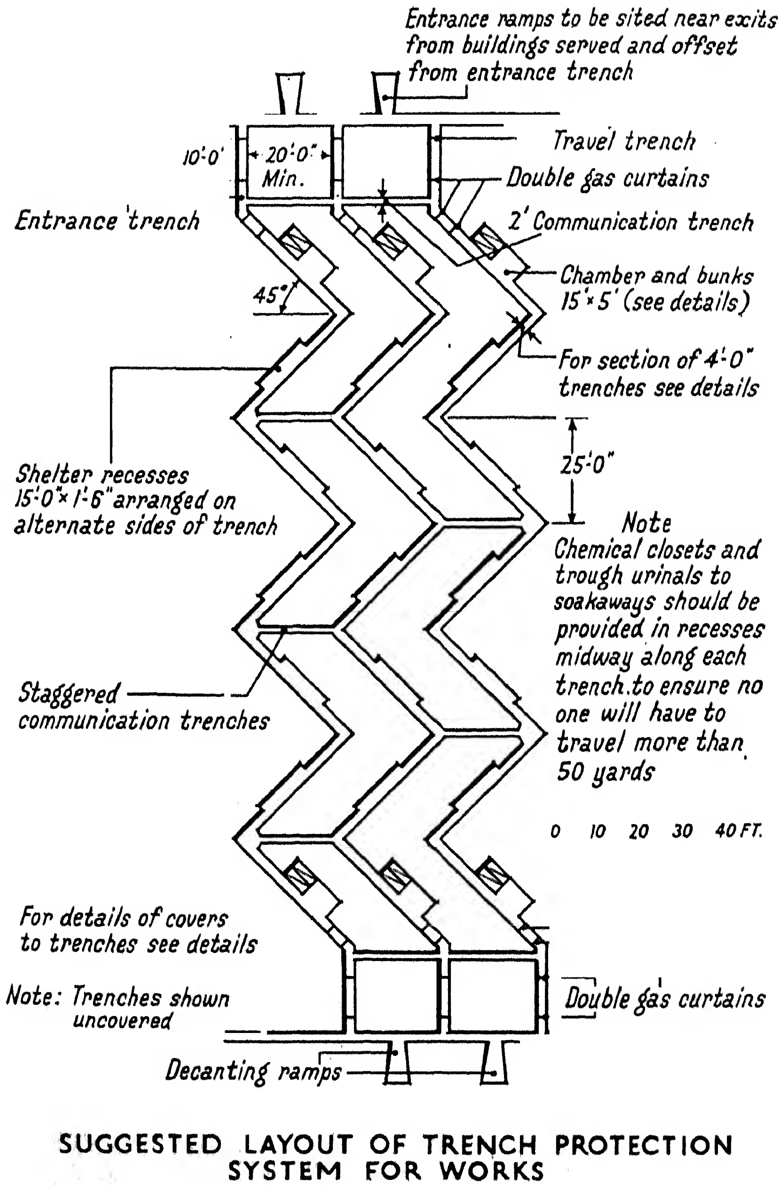


FIG. 162.—Layout of trench system which affords maximum localisation of effects of direct hit.

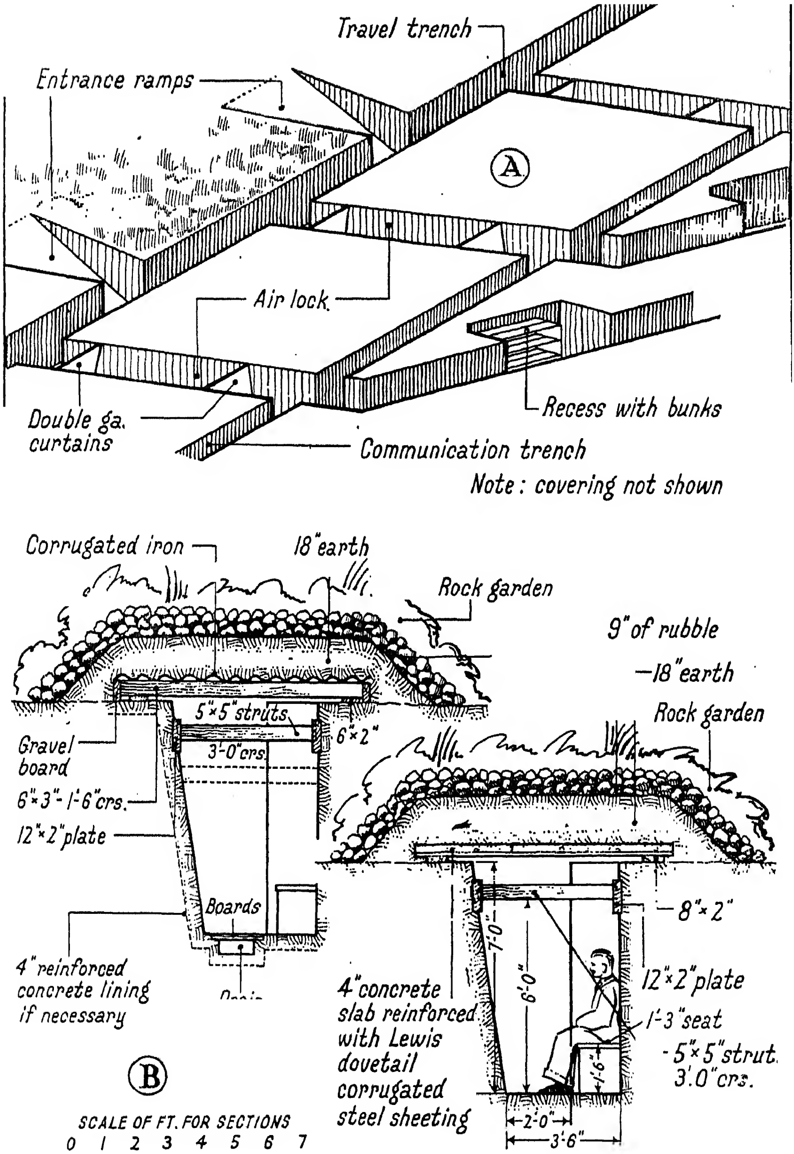


FIG. 163.—Showing (A) entrance to trench system Fig. 162. (B) and (C) alternative sections.

full depth, the shelter may be completed by banking up earth above ground level against the sides of the projecting revetment.

2. Along the bottom of each side of the trench make small holes 8 in. square by 6 in. deep for the reception of the side frame members, and put a 2 in. thickness of concrete in the bottom of the holes (see plan on p. 371). When the concrete has hardened, erect the frames in the trench, holding them

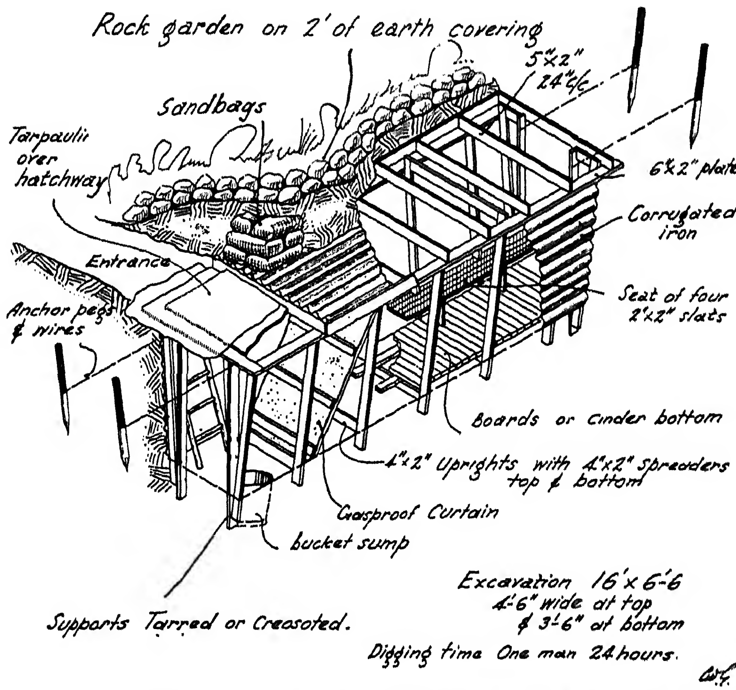


FIG. 164.—Sketch showing type of garden trench recommended by the Home Office. Lining with concrete as type W, Figs. 177 and 178, makes a more permanent shelter.

upright with temporary wooden struts or other means. Concrete the floor of the trench 3 in. thick, embedding the bottoms of the side frames in the process. When the concrete has hardened, insert the concrete lining slabs between the frames and the sides of the trench, and fill in earth to hold them against the frames (Fig. 177). Slots must be cut in the sides of the trench at the corners for reception of the lining slabs at either end.

3. Complete the roof (Fig. 177) and cover it with earth 21 in. thick. In order not to impair the amenities of the garden, the mound may be turfed over, or made into a flower bed or rockery. Instal ladder, seat, entrance, hatchway cover and gas curtain (if desired).

4. Fig. 177 shows the trench as it appears from above when finished.

Siting

In selecting a site for a trench system, due regard must be given to the following :—

1. Level of the ground in relation to the surrounding country, standing water level in the ground, if known, and the general slope which can provide natural drainage.

2. The proximity of large buildings, which, on demolition, would be likely to cause damage to the trench system.

3. The number of persons to be accommodated and the convenient point of entry for them.

It will obviously be desirable to keep the lowest point of any trench system above the level of the nearest main sewer, and preferably clear of danger of flooding from burst water pipes, holed tanks or burst reservoirs.

Planning

Fig. 165 shows diagrammatically a comparison between the various arrangements of trenches on plan. It will be seen that straight trenches are easily enfiladed with splinters in the event of one section of the trench being subject to a direct hit. The shaded portion of the trenches show the areas subject to the splinters and the areas within the circles those subject to destruction by the explosion itself. The figure also shows a section of trench as officially recommended in Spain ; the section, of course, is only suitable for trenches on dry sites with very firm ground, unless, of course, revetment of the trench sides is resorted to.

A general arrangement of a trench protection system for a factory is shown in Fig. 162, and attention is directed to the following points :—

1. The whole system is laid out on a zigzag pattern, with the object of localising the effect of a direct hit on any part of

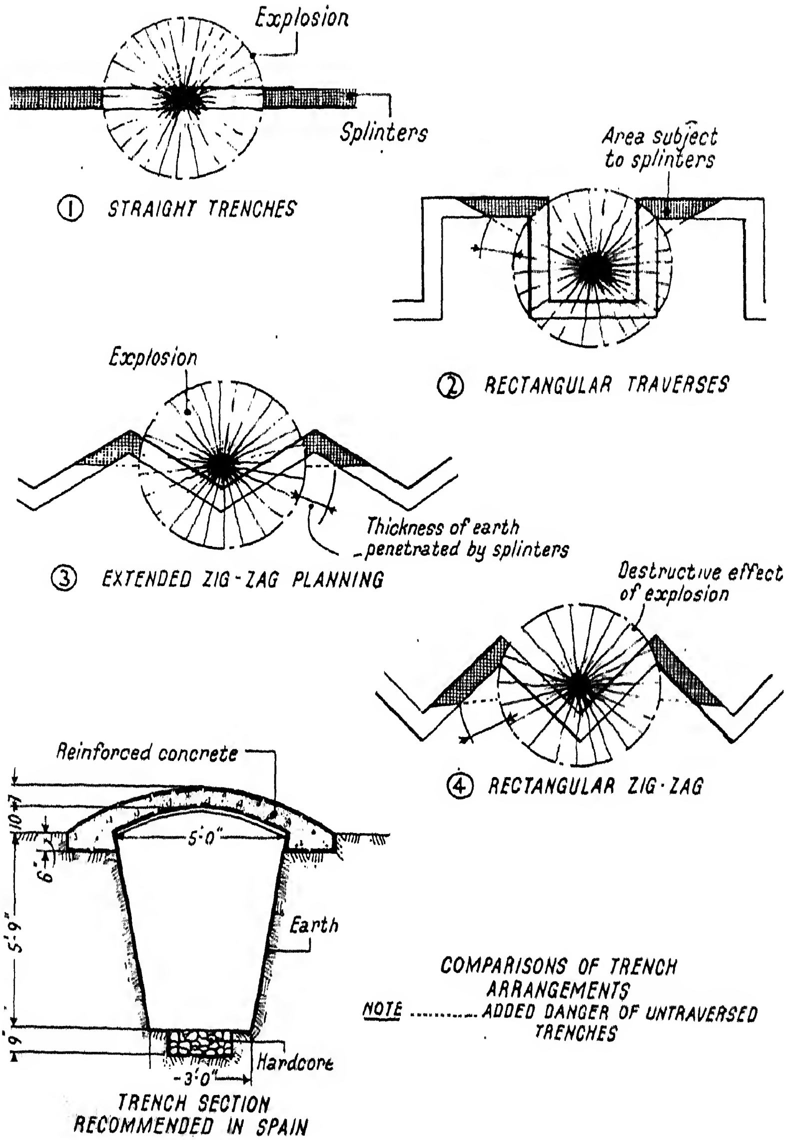


FIG. 165.—Showing advantages of traverses in trenches.

the system. There are a number of entrance ramps sited near the exits from the buildings served and offset from the entrance trenches with the same object in view.

2. The exit ramps are as remote as possible from the entrances.

3. The whole system is interconnected with communication trenches, thus affording free circulation through them and alternative means of exit.

4. In each traverse there are shelter recesses and near entrances and exits, chambers with bunks where casualties may receive attention.

5. At least one air-lock is provided at each entrance and exit, 10 ft. being allowed between gas blankets to allow for stretchers to be passed through.

6. Chemical closets and trough urinals connected to soak-aways should be provided in recesses midway along each trench to ensure that no one will have to travel more than 50 yards.

Construction

Alternative details of construction are given in Figs. 161 and 163. In Fig. 161 A shows a trench recess suitable for one person for each 1 ft. 6 in. of length. This section is suitable for trenches cut in solid well-drained ground, but as in all other cases a lining of reinforced concrete would provide a more durable and cleaner trench.

The trench is covered with strong timbers at close intervals supporting corrugated iron, which carries dry ballast heaped up to a circular section and having an average thickness of 18 in. Over this a bursting course of 12 in. of good ballast concrete is formed to the arched section shown, and the work is finished by the addition of 1 ft. of earth finished as a rock garden. Such a section is only suitable on dry sites, and the bottom of the trench should be laid to a rapid fall towards entrance and exit, in order to take away any water which might seep through the land. The cost of this form of trench construction is given in the summary at the end of this chapter. Section B in Fig. 161 shows a method of constructing a trench where considerable quantities of unconverted timber are available, such as in a wood. Attention is directed to the

RECESS FOR BUNKS IN TRENCH SYSTEM

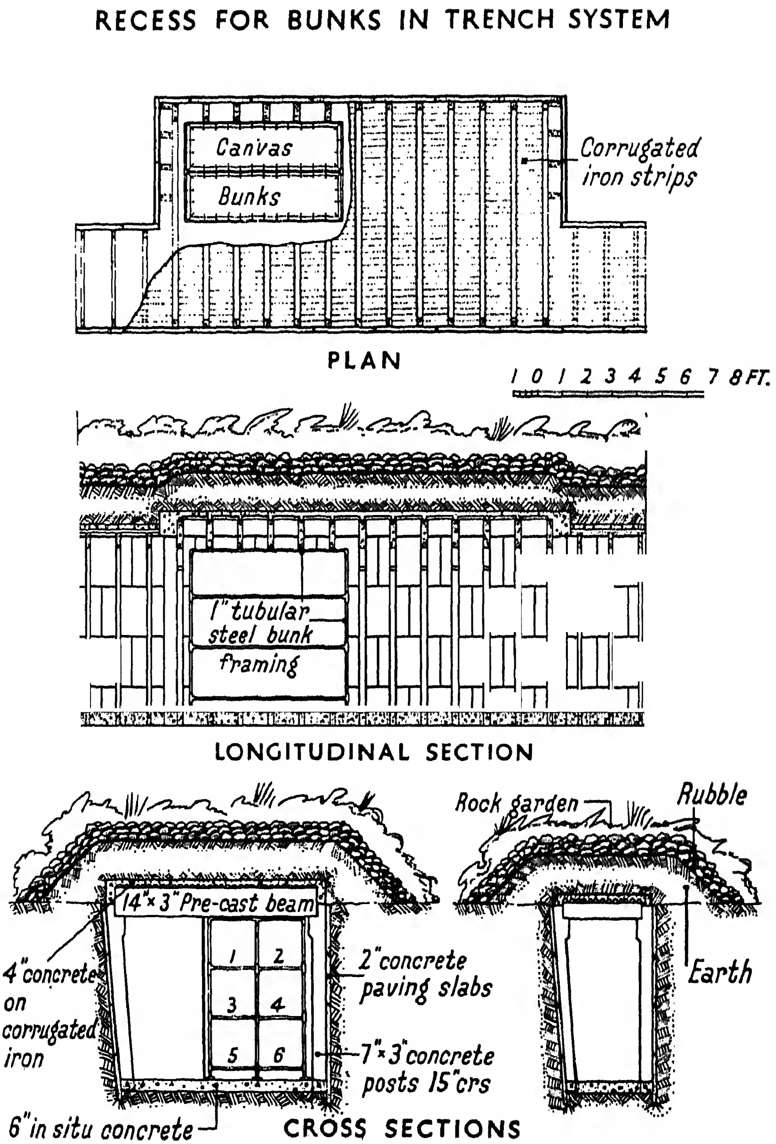


FIG. 166.—Bunks in recess in trench system, showing use of pre-cast reinforced concrete units in construction of revetment and cover.

necessity of driving the vertical timbers well into the solid base of the trench, and also to the desirability of wedging in distance-pieces between them along the bottom.

The arrangement will be clear from the illustration.

The earth is returned to the top of the trench after building paper has been laid completely round the outside of the timbering. An improvement would be the use of a heap of ballast or rubble over the trench above the natural ground level to act as a bursting course. These trenches are very strong, but are not so durable nor fire-resistant as those lined with reinforced concrete or constructed with arched pressed-steel sections.

Fig. 166 shows a method of construction of a recess for bunks in a trench system, using a combination of pre-cast and *in situ* reinforced concrete without the necessity of using temporary shuttering.

Temporary Timbering

There are three typical methods of strutting used for supporting the sides of excavated trenches, and these are shown in Fig. No. 167.

The first shows a satisfactory arrangement of temporary timbering for use where the ground is very firm. The poling boards, 5 ft. long, are placed in position in pairs, one board on each side of the cutting. They are kept apart by 4 × 4 in. struts, or short ends of scaffold poles cut and driven tightly between the boards.

The strutting is fixed as soon as the excavation is sufficiently deep and the poling boards are driven down as the work proceeds. In order to provide space for the men working in the trench, the minimum distance between sets of struts should not be less than 6 ft.

Where the ground is not so firm, additional poling boards are required, and these are held in position by waling pieces, generally as shown top right on Fig. 167. The process of fixing is to work from one end of the excavation, employing the first described method until a sufficient length has been excavated for the waling piece to be inserted and strutted up. After this the temporary strutting is removed and the lower depth of the excavation proceeded with.

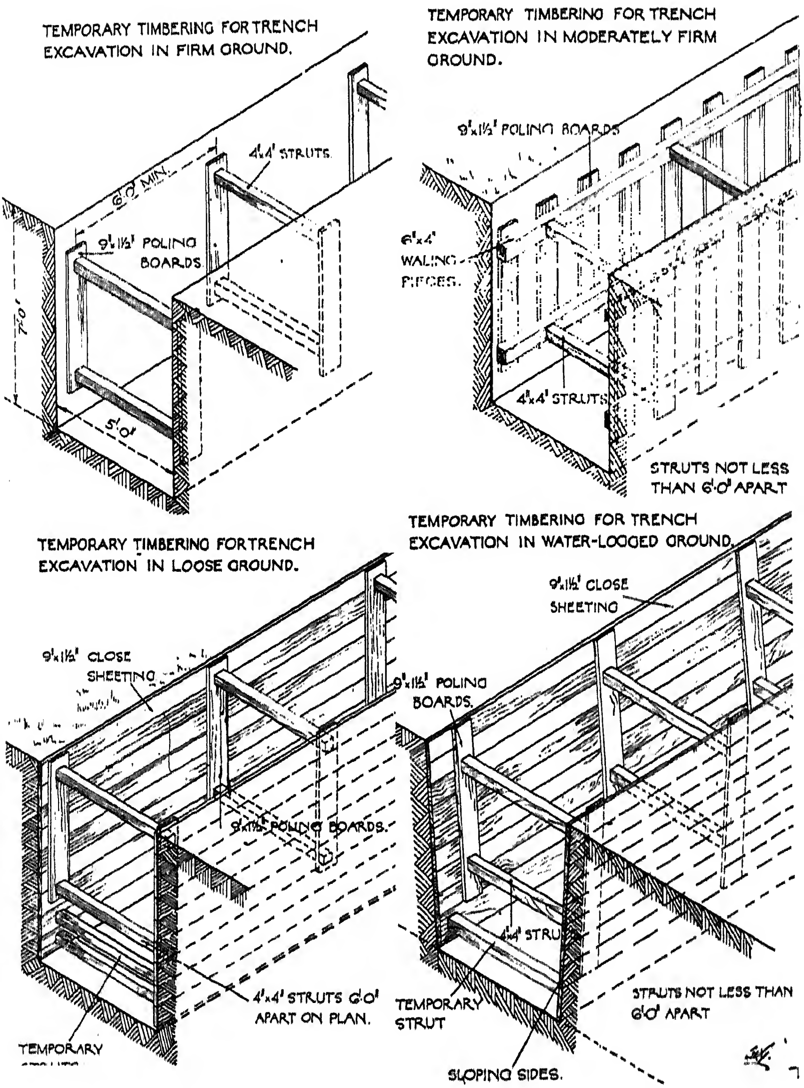


FIG. 167.—Showing temporary timbering for trench excavations.

When the earth is loose or soft, the method shown in the bottom left of Fig. 167 should be adopted. The method is to take out earth to a depth of 9 in., lay in and strut up a pair of sheeting boards, proceed with the next 9 in. depth, and so

on, until four sets of boards are in position and temporarily strutted. Short poling boards are then inserted, and when properly strutted the temporary struts are knocked out.

When the sides of the excavation are made to a slight batter, timbers are less likely to fall should the earth become drained and contract. This method facilitates the fixing of the struts, and is most suitable where waterlogged ground has to be dealt with.

As already pointed out, there are a number of patent systems for the permanent lining of trenches, but in all cases at least some of the temporary timbering cannot be recovered, and thus represents a permanent loss. Apart from this the cost of timbering is a very considerable item in the construction of trenches.

Revetting

The sides of all trenches should be revetted. One method is to use wooden frames with boarding, corrugated iron or any other suitable material behind. Where boarding is used, the trench should be excavated to a width 10 in. wider than the finished section, and revetting should be done with 1 in. boarding, supported by 4 by 2 in. uprights. The uprights should be driven 1 ft. 6 in. into the ground at centres not exceeding 3 ft. and held apart at the head by 4 by 2 in. spreaders. Another method is to use strong corrugated iron or dovetail steel sheeting (galvanised), driven in so that the corrugations or flutes are vertical. Horizontal walings of timber are then required at the top and bottom, supported at intervals with timber posts and provided with timber spreaders top and bottom. In light sandy soils the revetment can be effected by the use of brushwood or expanded metal hurdles, held in place with strong stakes provided with spreaders top and bottom, the rear of the revetment being backed up with turfs.

A type of all-metal dugout is now available, consisting of a metal lining to a trench with perforated floor over drainage channel and metal roof arranged for earth covering.

				£	s.	d.
Prices.	Size A.	3–4 people	. .	8	0	0
	" B.	6–7 "	. .	11	0	0

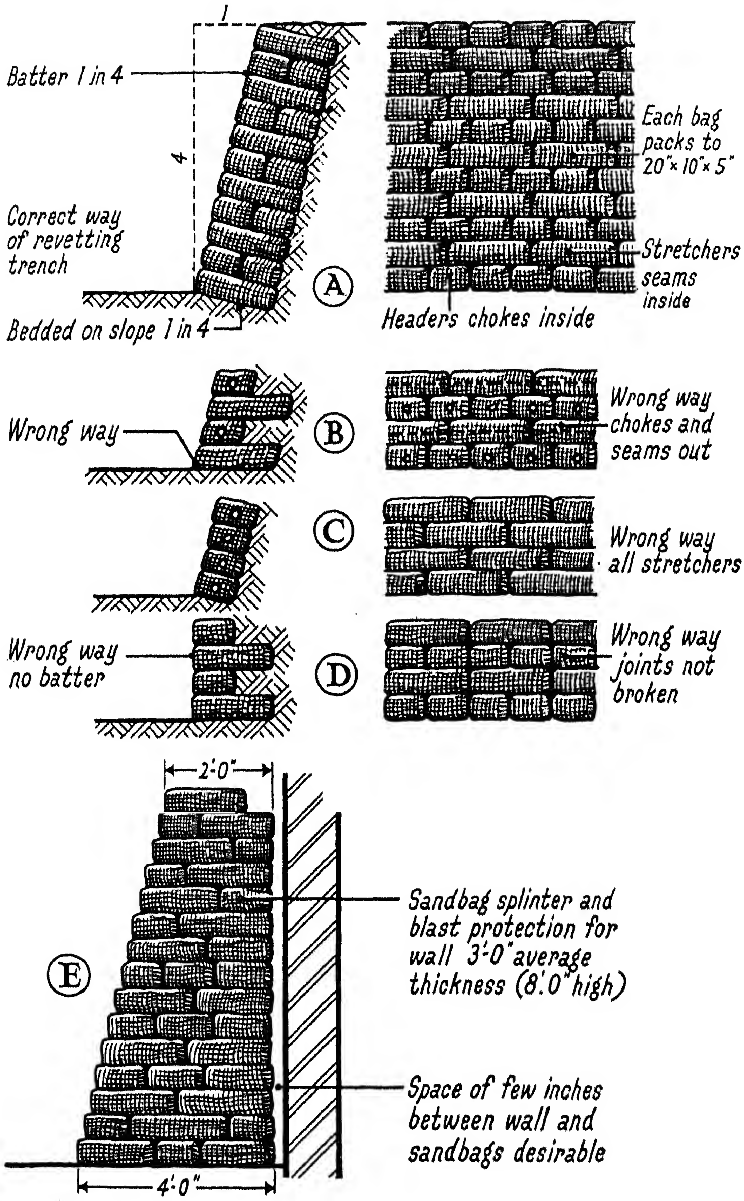


FIG. 168.—Sand-bagging. (A) and (E) correct. (B), (C) and (D) incorrect.

delivered. C.P.C. Metal Works, West End, Southampton.

Undoubtedly the most satisfactory and permanent way of revetting trenches is by the use of *in situ* reinforced concrete or pre-cast reinforced concrete slabs. An excellent way of forming a covered trench is to excavate to some 6 in. below the finished depth, lay 2 in. ground concrete and erect thereon steel arched sections of galvanised corrugated iron or dovetail sheeting, over which the concrete walling and roof can be placed. The laying of an additional 4 in. of concrete at the bottom of the trench completes a clean hygienic interior and provides the necessary base spreader for the walls.

Sand-bagging

In the revetment of trenches sand-bagging plays an important part, and the following notes will be of interest :—

The service pattern sand-bag is of jute and measures 33 by 14 in. when empty. A bale of 250 weighs 96 lb., and sand-bags are available at £10 8*s*. 6*d*. per 1,000.

Sand-bags should be three-quarters filled and the neck tied round with string provided for the purpose.

The bag contains ½ cub. ft. and should measure when laid 20 by 10 by 5 in.

It should always be laid with the mouth tucked under and the seam and the choke inside the work.

The party for filling sand-bags should consist of three men ; two men hold and tie the bags while one man shovels the earth into them.

Three men can fill forty-five bags in one hour, and for building two men working together can lay thirty sand-bags in one hour. The carrying party will depend upon the distance.

In building a wall, alternate courses of headers and stretchers should be used, and care should be taken to break vertical joints (see Fig. 168).

Grain sacks or bags which may be available can be substituted for sand-bags. They usually contain 2 bushels (2½ cub. ft.) of grain, so that if they are used instead of sand-bags they should not be more than half filled, otherwise they are too heavy to handle.

It is not necessary to close up or tie a sack if the mouth is

carefully folded under it when it is being placed in position, as the weight of the sack will prevent loss of earth.

As a rough guide to the number of sand-bags required, it may be mentioned that a sand-bag wall, 8 ft. high, constructed of Army pattern sand-bags in the manner indicated at E in Fig. 168 would require forty to fifty sand-bags per foot run.

In revetment, if bags are filled with concrete and well punched into position, a very permanent construction will be made.

Preservation of Sand-bags

Under normal war conditions, sand-bags are not required to remain in position for an indefinite period; sand-bagging of dugouts, parapets and buildings is undertaken at relatively short notice in response to the changing needs of a battle-action situation.

It is conclusively established by tests that *sand-bags in position* :—

(*a*) Begin to deteriorate within three to four weeks.

(*b*) Completely disintegrate within four to five months according to position and condition.

Sand-bags are made from JUTE HESSIAN. Wherever JUTE HESSIAN is required and specified by the War Office for *lasting* use (*i.e.*, wherever it is required for conditions other than those occurring in a normal battle zone where sand-bagging is temporary in location), it is required and specified by the War Office to be proofed by the CUPRAMMONIUM process. All fabrics subjected to exposure, in use by the War Office, Admiralty, Air Ministry, etc., are proofed. The CUPRAMMONIUM (original "WILLESDEN") proofing gives protection against rot, damp and mildew.

In view of the fact that civil defence arrangements involve the use of sand-bags, which *will remain* in situ *for an indefinite period before and during hostilities*, it becomes apparent that :—

(*a*) Buildings and emplacements may be committed to the insecure protection of sand-bags which will inevitably deteriorate to the point of complete disintegration inside four to five months, with a consequent dispersal of sand to an acutely dangerous extent.

(*b*) The problem of entirely replacing sand-bag requirements

may have to be faced *every six months whilst actually* in situ, and the even more acute problems raised by the necessity of replacing sand, and of getting both labour and time for refilling operations, perhaps actually during hostilities.

This serious situation can be met in one of two ways :—

(*a*) At once insisting upon rot-proofed sand-bags.

(*b*) Sending existing sand-bag supplies to be proofed.

Sand-bags can now be made permanently rot-proof and mildew-proof by the Willesden Paper and Canvas Works Ltd. under the " WILLESDEN " CUPRAMMONIUM process for under 1*d.* each, with discounts for large quantities handled at one time.

A very important additional reason for having sand-bags rot-proofed has been disclosed by the war in Spain. In many cases machinery, anti-aircraft guns, etc., were protected by walls of sand-bags. These rotted in a month or two, and the sand was blown into the working parts of the guns and machinery. In many cases these were temporarily put out of action, and only brought back into operation after great expense and loss of valuable time.

Storage of Sand-bags

Sand-bags can be stored for considerable periods—say, up to twenty years, provided the following precautions are observed :—

(i) The store must be absolutely dry. If damp is present, spontaneous combustion is likely to set in.

(ii) The bales should, if possible, be piled on grids a few inches above the floor, and there should be a free passage of air around the piles of bales.

Alternatives to Sand-bags

If sand-bags are not readily available, wooden boxes filled with earth will serve as well.

Failing wooden boxes, an earthen rampart may be used.

A portable sand-bag filling machine, weighing 70 lb. and provided with " wheelbarrow " movement, is now available at £5 5*s*. from the Gas Proofing Co. Ltd., and it is shown in Fig. 169, and by its use it is claimed that a squad of four men, filled, folded and laid 230 sand-bags per hour. This great saving of

time and labour will release men for other important work, and will be of great benefit in an emergency.

Apart from this, the use of the machine in an emergency enables the sand-bags to be stored in the interim, thus avoiding deterioration and rapid destruction of protective works, due to rotting of the bags when filled.

It may sometimes be found that a squad of workers are not available for a sand-filling task, and to meet this contingency

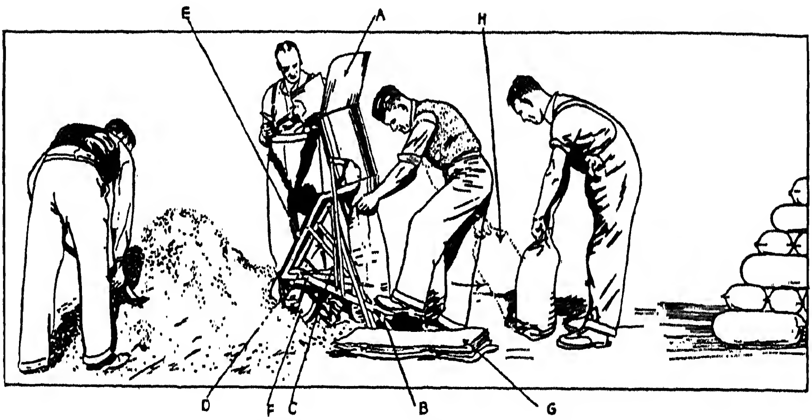


FIG. 169.—Sand-bag filling machine.

A, Hopper, into which sand is shovelled by two men. B, Treadle, foot-operated by machine minder. When treadle is pressed down it operates a patent device in the hopper, which precipitates the sand into the bags. C, springs controlling the action of the treadle. D, retractable handles, which, when raised, automatically lock into position, ready for wheeling the filler away. E, shield preventing sand accumulating underneath the hopper. F, wheel, 12 in. in diameter with solid rubber tyre. G, empty sand-bags. H, dotted lines show how sand-bags are passed from the machine minder to man folding and laying.

the author has devised an appliance, shown in Fig. 170, which can be purchased for 2*s*. 6*d*. By its use one person can fill, fold and lay no less than forty sand-bags per hour. The operation is to place the empty sand-bag round the ring—the top edge being hooked on to the tags provided. After filling, the sand-bag is lifted off, the end twisted and turned under and the bag placed in position.

The Iron Sapper is a device by which one man can, unaided, fill 100 bags in one hour. Uniformity of shape of filled bags is

a special feature. Price 12*s*. 6*d*. each from Universal Air Defence Services, 91, Gower Street.

Notes on Digging and Construction of Trenches

For the purpose of calculating the amount of untrained civilian labour required in the execution of trench works, the

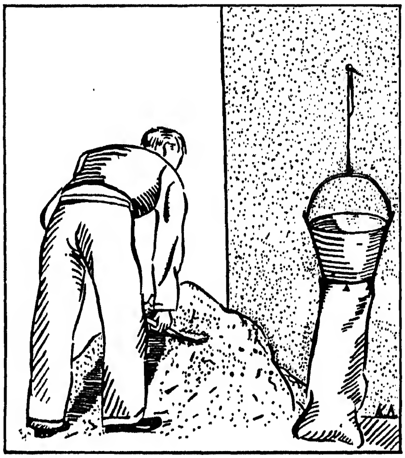


FIG. 170.—Arrangement to enable one man to fill sand-bags unaided.

figures given in the following table, being about half of the allowances made for trained militia, should be a safe guide.

It is assumed that the work is already set out, that the work is carried out by day, and that the weather is favourable.

The figures make no allowance for the use of sand-bag filling machines.

TRENCHES

Home Office Specification in Regard to Permanent Lining of Trenches

Early in 1939 the Home Office issued a composite specification and bill of quantities for pre-cast concrete units in linings to trench shelter accommodation based upon Home Office designs. The specification calls for materials to comply with the British Standard Specification and concrete having a minimum strength requirement at twenty-eight days of 2,500 lb. per sq. in.

TABLE LXXXVIII

Item No.	Nature of work.	No. of workers.	Time.	Quantity.	Task per man per hour.	Tools for party.	Remarks.
A	B	C	D	E	F	G	H
	EARTHWORK *Excavation of Trenches*						
1.	(*a*) In soft, sandy ground.	1	1 hour	15 cub. ft.	15 cub. ft.	1 pick and 1 shovel	(i) The tasks given in Col. E allow for the earth being thrown out of a trench, 4 ft. deep, to a distance of 8 ft., or for throwing earth upwards to a height of 6 ft. When the earth has to be thrown further than this, one shoveller should be added for every two diggers.
		1	4 hours	45 cub. ft.	—	1 pick and 1 shovel	
	(*b*) In medium ground, or soft ground with stones or small roots.	1	1 hour	10 cub. ft.	10 cub. ft.	1 pick and 1 shovel	(ii) When the depth of the trench is more than 4 ft., one shoveller should be added for every two diggers to clear the excavated material.
		1	4 hours	30 cub. ft.	—	1 pick and 1 shovel	
	(*c*) In hard ground, or medium soil with stones and roots.	1	1 hour	$7\frac{1}{2}$ cub. ft.	$7\frac{1}{2}$ cub. ft.	1 pick and 1 shovel	(iii) Sticks to clean shovels in wet clay. Crowbars for rocky ground. Hand-axes or billhooks for cutting roots. Spare pick handles, etc., must be provided when required by the nature of the ground.
		1	4 hours	20 cub. ft.	—	1 pick and 1 shovel	
2.	Shovelling earth ready excavated.	1	1 hour	20 cub. ft.	20 cub. ft.	1 shovel	(iv) Allows for 10 ft. horizontal throw.
		1	4 hours	60 cub. ft.	—	—	

3.	Excavating earth and loading into wheelbarrows, or baskets.	1	—	As under Serial No. 1.			(v) Spare wheelbarrows, etc., must be available, so that the digger can fill one while the carrier is emptying the other. Sufficient wheelbarrow or basket men must be allowed so that diggers are not kept waiting.
4.	Moving earth 25 yds., depositing it and returning—						
	(a) In wheelbarrows.	1	4 mins.	1 cub. ft.	15 cub. ft.	2 wheelbarrows	(vi) If the distance from the work to the dump is more or less than 25 yds. increase or decrease the time and task accordingly. For example, if the distance is 40 yds allow $\frac{40}{25} \times 4 = 6{\cdot}4$ minutes per cub. ft. = 75 cub. ft. in eight hours. (vii) In calculating the distance, add 5 ft. for each foot of climb for wheelbarrows and $2\frac{1}{2}$ ft. for each foot of climb for baskets. For example, if the distance is 20 yds. and the man pushing the wheelbarrow has to climb 10 ft., the task is worked out as though the distance were 20 yds. plus 10×5 ft. = 37 yds. nearly.
	(b) In baskets	1	4 mins.	$\frac{1}{2}$ cub. ft.	5 cub. ft.	2 baskets	(viii) Planks are required to make roads for wheelbarrows.
	(c) In sandbags (see below).	1	4 hours	20 cub. ft.	5 cub. ft.	2 baskets	(ix) Wheelbarrows cannot climb a steeper slope than 1 in 8 or baskets a steeper slope than 1 in 4. (x) There must be sufficient barrows, etc., so that there is always one being filled while the other is being emptied.

Item No.	Name of work.	No. of workers.	Time.	Quantity.	Task per man per hour.	Tools for party.	Remarks.
A	B	C	D	E	F	G	H
5.	REVETMENTS Sand-bag revetment:						
	(a) Filling sand-bags.	3	1 min.	1 bag	10 bags	1 shovel	(xi) Two men holding and tying, one man shovelling. (xii) Sand-bags to be three-quarters filled (holding $\frac{1}{2}$ cub. ft.). (xiii) In calculating tasks for carrying bags, calculate distance as for carrying baskets in notes (vi) and (vii) above.
	(b) Carrying sand-bags 25 yds., dumping and returning.	1	4 mins.	1 bag holding $\frac{1}{2}$ cub. ft. of earth.	15 bags	—	(xiv) Builders work in pairs when possible. (xv) 1 sq. ft. of revetment means 1 sq. ft. measured on the outer face of the sand-bag wall. For example, a revetment 10 ft. long and 4 ft. high = 4 × 10 = 40 sq. ft., and would take one pair of builders 4 × 40 = 160 mins., and would require 120 sand-bags.
	(c) Building sand-bag revetment.	2	4 mins.	1 sq. ft. of revetment, *i.e.*, 3 filled bags.	$7\frac{1}{2}$ sq. ft. = $22\frac{1}{2}$ bags	1 beater	(xvi) A beater may be either a special wooden beater, or billhook, or a shovel. (xvii) The sheeting consists of corrugated iron sheets, expanded metal hurdles, brushwood hurdles, planks or loose brushwood.
	(d) Sod revetment:						
	(i) Cutting sods. (ii) Carrying sods to site, etc.	3	6 mins.	5 sods (see items above)	16 sods	3 sharp spades	(xviii) Size of sod, 18 × 9 × $4\frac{1}{2}$ in. One sod to be taken as $\frac{1}{2}$ cub. ft.

	(iii) Building sods.	2	6 mins.	1 sq. ft. of revetment.	—	1 shovel and spade	(xix) Allow five sods, each $18 \times 9 \times 4\frac{1}{2}$ in., for each square foot of surface revetted 18 in. thick.
6.	Sheeting and picket revetment.	10	1 hour	10 ft. run	—	2 mauls or sledge-hammers 2 shovels 1 pick 1 handsaw 1 handaxe 1 pair pliers 1 crowbar (in rocky soil)	(xx) Distribution of working party :— Two men driving anchorage pickets. Two men driving revetment pickets. Two men placing sheeting. Two men wiring pickets. Two men trimming and filling. (xxi) With a smaller working party, allow longer time.
7.	Sheeting and "A." frames.	7	1 hour	10 ft. run of trench	—	2 picks 2 shovels 2 mauls 1 handsaw 1 hammer Nails	(xxii) The time given does not include digging out the trench to full section. (xxiii) The sheeting consists of corrugated iron sheets, expanded metal hurdles, brushwood hurdles, planking or brushwood. (xxiv) For each corner add thirty minutes to time required for revetting the trench. (xxv) Distribution of parties :— Two men supply materials. Three men placing frames and sheeting. Two men trimming and packing (see Note (xxi) above).

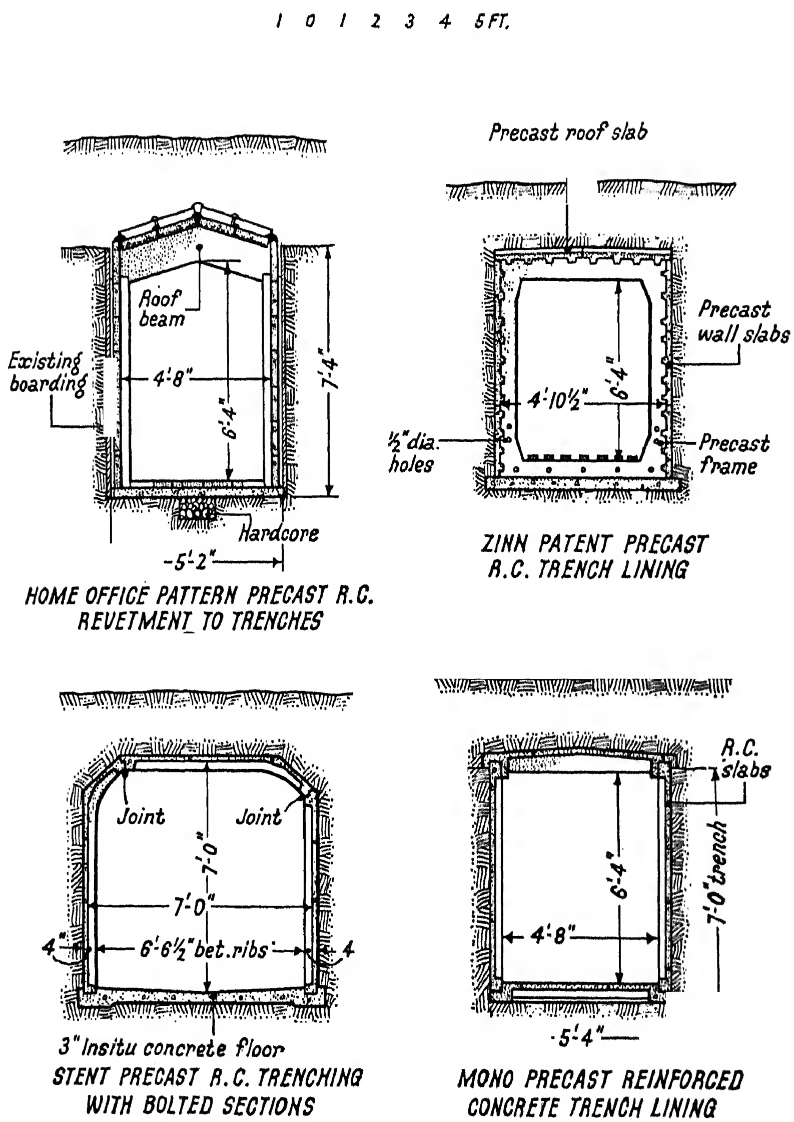


FIG. 171.—Showing approved types of pre-cast reinforced concrete trench linings.

The units are intended to be laid dry with the exception of the roof slabs; the section is shown as Type A on Fig. 171.

In each alternate bay the uppermost roof slabs are intended to be buried on top of the lower slab in Portland cement and sand (1 : 3) mortar. The joints between the roof slabs in the running length of the trench are intended to be grouted with similar mortar.

The design is based on the assumption that the angle of repose of the ground is or exceeds 40 degrees above the horizontal, and the following are brief particulars of the units in one bay 3 ft. 3 in. run of trench lining.

No. 2 post, sizes 6 by 6 in. overall and 6 ft. 3 in. long, rebated on both sides and reinforced with and including one $\frac{11}{16}$ in. diameter and two $\frac{1}{2}$ in. diameter rods, and with $\frac{1}{8}$ in. diameter rods in links at 2 in. and 6 in. pitch, including moulds.

No. 1 beam, 5 ft. 2 in. long and 3 in. thick, shaped to each end on top and underside, and 11 in. mean depth and with nib at bottom of beam each end, reinforced with and including two $\frac{5}{8}$ in. diameter cranked rods hooked at ends and with $\frac{3}{16}$ in. diameter rods as stirrups at 3 in. and 6 in. pitch, including moulds.

No. 1 ground beam, 5 ft. 2 in. long, size $8\frac{1}{2}$ by 5 in. overall, twice rebated on top and reinforced with and including two $\frac{1}{2}$ in. diameter cranked rods and four $\frac{3}{16}$ in. diameter rods hooked at ends, and with $\frac{1}{4}$ in. diameter links at 3 in. and 6 in. pitch, including moulds.

No. 3 floor slabs, 12 in. wide, 2 in. thick and 2 ft. 10 in. long, including fabric reinforcement composed of No. 9 I.W.G. wires at 3 in. centres and No. 12 I.W.G. wires at 12 in. centres.

No. 4 roof slabs, $13\frac{3}{4}$ in. wide, 3 in. thick and 3 ft. 6 in. long, reinforced with and including fabric reinforcement as described for wall slabs, including moulds.

No. 14 wall slabs, 12 in. wide, $2\frac{1}{4}$ in. thick and 2 ft. $11\frac{1}{2}$ in. long, reinforced with and including fabric reinforcement composed of No. 7 I.W.G. wires at 3 in. centres and No. 10 I.W.G. wires at 12 in. centres, including moulds.

Cost per bay of 3 ft. 3 in. run of lining, at site, £2 15s.

Notwithstanding the fact that the Home Office have prepared a design published with their general specification, alternative

Table LXXXIX

Summary

Inclusive Cost per yard run of Executing Trench Lining Complete, including Withdrawing Existing Timber and Filling in Excavation Over

	£	s.	d.
Cost of pre-cast concrete units in lining, on site, including special castings for intersections and building emergency exits	2	14	0*
Cost of assembling units in trenches . . . . . Cost of grouting and bedding roof slabs in cement mortar, as described . . . . Cost of withdrawing existing timbers in trenches as is necessary . . . . Cost of returning and filling earth over top of completed shelter	1	1	0
	£3	15	0

* *Note.* The difference between the figure of £2 14*s.* per yard run and the figure of £2 15*s.* per bay of 1 yd. 3 in. (see above) is intended to cover the extra cost of intersections, dead ends and exits.

designs may be submitted, provided they comply with the following general requirements :—

Extract from General Specification Setting out Standards to be Fulfilled by any Design Submitted for Approval

1. Trenches may be lined with concrete, or with steel, provided it is suitably treated to prevent rust and deterioration, or by means of a combination of these materials.

2. The minimum width between the sides of the trench when lined shall be not less than 4 ft. 8 in. This does not apply to the width between the upright posts which may be less. The minimum height at any point in the centre of the trench shall be not less than 6 ft. 4 in.

The cubic contents (air space) shall be not less than 31 cub. ft. per foot run.

3. The framework and roof of the lining shall be of sufficient strength to carry a load of 400 lb. per sq. ft. The sides shall be capable of withstanding a thrust varying from 100 lb. per sq. ft. at the top to 250 lb. per sq. ft. at the base. Where the

angle of repose of the material is less than 40 degrees or thereabouts above the horizontal, the sides shall be capable of withstanding correspondingly increased thrusts up to a maximum of 200 lb. per sq. ft. at the top and a maximum of 400 lb. per sq. ft. at the base.

Designs in reinforced concrete shall be based on the Code of Practice for Reinforced Concrete Structures, with the exception that the stresses therein laid down may be increased by a maximum of 25 per cent.

Designs in steelwork shall be based on the British Standards Institution Specification for "The Use of Structural Steel in Buildings," No. 449—1937, with the exception that the stresses therein laid down may be increased by a maximum of 25 per cent.

4. The upright members of this revetment shall rest on foundations or slabs in such a manner that the safe limiting pressure per square foot for the soil concerned is not exceeded. They should be firmly strutted apart, both at the top and at the bottom. Arch designs will only require strutting at the bottom.

5. The joints in the roof of the trench shall be grouted or otherwise treated to render them reasonably waterproof. This is not essential in the case of the side members.

6. It is not essential that the floor should be completely covered with concrete or flagstones. It can be filled with shingle or other porous material. Where clinker or ashes are used for this purpose, they should be kept from contact with the lining if this is of steel.

7. A ventilator should be fixed in each corner, or length of trench, in such a manner that it can be converted in wartime to form an emergency exit. A concrete or metal cover with a grid in the centre would be suitable for this purpose.

Numerous alternative designs have been submitted to and approved by the Home Office, and twenty-five of these are illustrated herewith, a brief description of each being given below.

The "Standard" trench (minimum width 4 ft. 8 in.) is for two lines of seats, and the block trench, 7 ft. wide, is for three lines of seats.

With the former arrangement, however, the aggregate wall

floor and ceiling surface per person accommodated works out normally to 19 sq. ft. against only 15 sq. ft. per person in the 7 ft. tunnel shelter. This is greatly in favour of the narrower tunnel as the dissipation of heat from the interior is a function of the total surface, apart from which the smaller interior section minimises loads on roof and floor. The figures will, no doubt, be self-explanatory and the table of comparative costs of interest.

The prices given in this table are believed to be accurate,

TABLE XC

TRENCH LININGS

Index.	Name.	Approximate Costs per Yard Run.						Remarks.
		Units d/d. (25 miles.)			Complete.			
		£	s.	d.	£	s.	d.	
A.	Home Office pattern	2	14	0	5	0	0	Standard width, 4′ 8″.
B.	Zinn pre-cast	2	10	0	5	10	0	,, ,, ,,
C.	Stent pre-cast block	4	5	0	8	15	0	Block system, 7′ wide.
D.	Mono pre-cast	2	14	0	5	10	0	Standard width, 4 8″.
E.	Stent pre-cast	3	0	0	6	10	0	,, ,, ,,
F.	Trussed Concrete Steel Co.	4	5	0	10	0	0	7′ 0″
G.	Rapid Flooring Co.	3	2	6	6	0	0	7 0″
H.	Trussed Concrete Steel Co.	2	18	6	5	0	0	Standard width, 4′ 8″.
J.	Self-centering *in situ*	2	7	0†	10	0	0	,, ,, ,,
K.	Girling's pre-cast arch	2	14	0	5	14	0	Standard width, 4 8″.
L.	Costain pre-cast rect.	2	18	0	7	0	0	,, ,, ,,
M.	Trianco pre-cast rect.	2	5	10	5	0	0	,, ,, ,,
N.	Pre-cast polygonal concrete	6	10	0	14	0	0	6 6″
O.	Trocoll spun pipe	7	17	6	14	0	0	6′ 6″
P.	Costain sectional circular	6	2	0	14	0	0	6′ 8″
Q.	Trollope and Coll's Gothic	7	17	6	14	0	0	—
R.	Costain's locksheet steel	8	0	0	14	0	0	Steel arched, 7 0″.
S.	Westwood's steel trough	1	10	0	5	10	0	Steel rect., 6′ 0″.
T.	Nissen steel arch	4	4	0	8	8	0	Steel arched, 8′ 0″.
U.	Steel vee interlocked	3	10	0	6	10	0	14 G. steel arched, 4′ 10½″.
V.	Timber		—		4	5	0	4′ 6″–4′ 8″
W.	C. & C.A. pre-cast	2	18	0	5	5	0	Garden type.
X.	Costain's pre-cast arched	3	19	0	12	10	0	7′ 0″
Y.	*In situ* concrete		—		5	5	0	4 8″
Z.	Glover pre-cast	2	14	0	4	18	0	4′ 8″

Installing in excavated trenches, £1 per yard run.
Excavation, £1 12*s*. per yard run.

* Includes excavation, construction and banking earth over, but not seating, lighting or ventilation, and refers to straight trench only to section illustrated.

† All reinforcement.

but are only given as a general guide to the reader, and are not, of course, binding upon manufacturers.

When the conditions of the ground are suitable, the *in situ* monolithic type of reinforced concrete lining has superlative properties, but where the ground is bad, the caisson type, affording protection to the workmen during construction—without the use of temporary planking and strutting—has much to commend it.

Trench Linings

Type A (Fig. 171). This is the Home Office design and consists of some twenty-seven separate pre-cast units per yard run.

Type B (Fig. 171) is made with pre-cast rigid cross frames erected at 3 ft. centres along the trench.

Existing timbers are wedged off from them, thus permitting the safe withdrawal of the timber strutting.

The timber sheeting is then removed and replaced by ribbed reinforced concrete side slabs.

Pre-cast roof slabs and an *in situ* floor completes the lining.

Type C (Fig. 171) is constructed of pre-cast interlocking flanged concrete plates bolted together. The illustration shows the "Britannia" 7 ft. trench.

Type D (Fig. 171) is completely pre-cast with ribbed sections grouted at the joints. The units are 1 ft. 6 in. wide and are set to "break joint." The floor slabs weigh 225 lb., side slabs 250 lb. and roof slabs 225 lb. approximately. Posts and beams are used at intersections and special roof slabs at "man-hole" exits.

Type E (Fig. 172) comprises the "Britannia" system for 5 ft. trench linings.

Type F (Fig. 172) is made up of 4 in. pre-cast reinforced concrete walling units 15¼ in. wide, 6 in. pre-cast roof units 16 in. wide, 7 by 4 in. concrete struts at 5 ft. 1 in. centres and 7 by 3 in. concrete walings at roof level. The whole set on a 5 in. *in situ* concrete base recessed for the wall units.

Type G (Fig. 172) is constructed of the well-known pre-cast interlocking "bull-head rail" sections made by the Rapid Flooring Co. They span from corner to corner and are grouted at the joints.

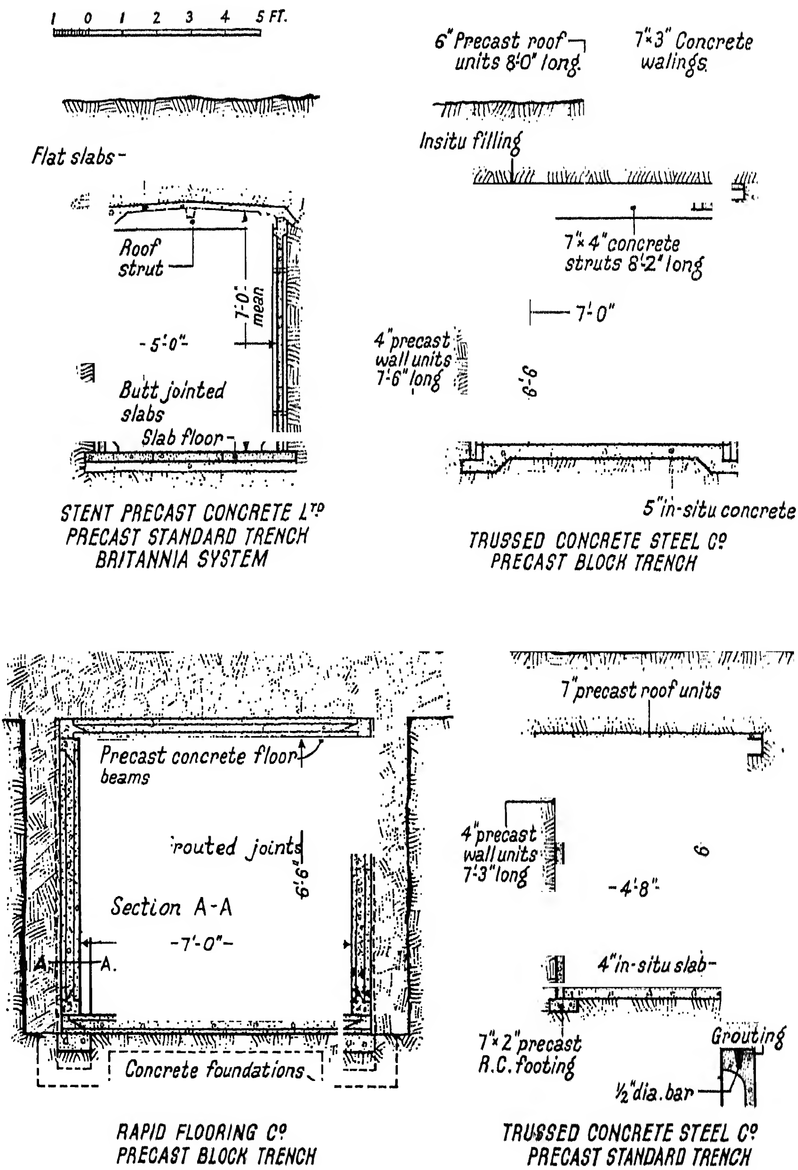


FIG. 172.—Approved trench lining systems in pre-cast reinforced concrete.

Type H (Fig. 172) is similar to Type F only with the narrower trench. The roof units are notched to set over the wall units and the struts and walings are not necessary.

Type J (Fig. 173). This shows a form of *in situ* reinforced concrete shelter, as designed by the Expanded Metal Co. Ltd., using self-centering expanded metal. In the execution of this work it will be noticed that no heavy sections have to be handled and that temporary supports only are required. The ribbed expanded metal can be delivered either flat or curved as required, and the work is speedy and economical in execution. The material acts as reinforcement and permanent centering to the walls and roof, and in the case of the approved rectangular section, which has side splays at the roof 1 ft. 6 in. deep and 1 ft. 2 in. wide, the thickness of the lining is 4 in., including a ½ in. thick rendering on the inside of the Ribmet. The ribs occur at about 5 in. centres and stiffen the expanded metal to such an extent that this only requires supporting at intervals of 2 ft. 6 in. during the concreting process.

The Ribmet is extended from the floor level up both sides and over the soffit of the roof and the roof is reinforced with additional bar reinforcement in ½ in. diameter mild steel bars at 12 in. centres. The ground concrete is 3 in. thick, thickened to 4 in. under the side walls and need not be reinforced except in the case of very bad ground, where upward pressures are to be expected. The concrete mix recommended is the ordinary 1 : 2 : 4, and except in the case of very bad ground no external shuttering is required.

Type K (Fig. 173). This shows pre-cast reinforced concrete trench linings made and supplied by Girling's Ferro-Concrete Co. Ltd. The complete assembly consists of pre-cast reinforced concrete floor units, which are grouted between the ribs when fixed, and pre-cast reinforced concrete arched ribs of the section shown on the drawing bolted together at the crown. The approximate price for these units—delivered in the Metropolis but not erected—is 54*s*. per linear yard completed, 32*s*. for each dead end and £4 12*s*. for emergency exit or ventilator to project 2 ft. above the top of the reinforced concrete shelter.

Type L (Fig. 173) *Concrete Trench Lining Units.* These are supplied by Richard Costain Ltd. and are erected on an *in situ*

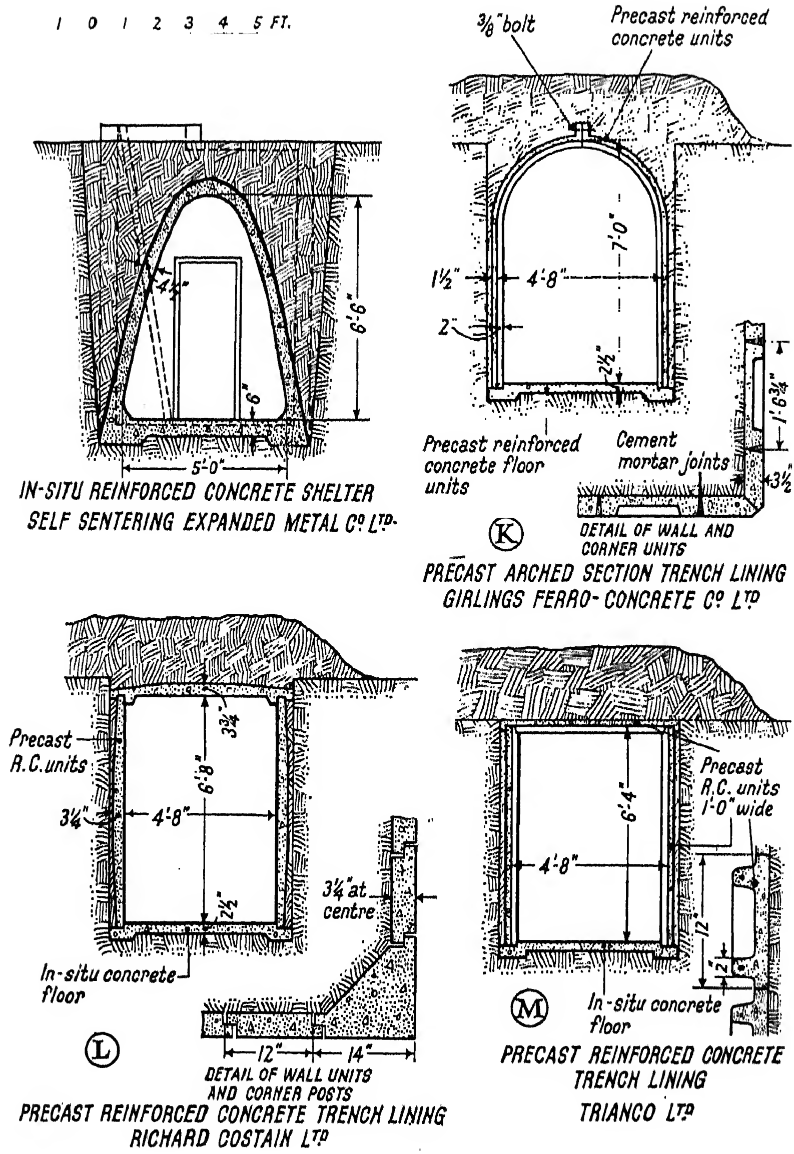


FIG. 173.—Various forms of trench linings in reinforced concrete.

concrete floor. Both side slabs and roof slabs are thicker in the middle where the greatest bending stress is obtained. Wall and roof sections are 12 in. wide and with rebated edges, which are grouted up during erection, and each section is reinforced with three $\frac{3}{8}$ in. diameter rods with two $\frac{1}{8}$ in. diameter spacers. The price of the material per yard, comprising six wall sections and three roof sections, is £2 13*s.* 6*d.* *ex* works.

Type M (Fig. 173). This is a pre-cast reinforced concrete trench lining system sold by Trianco Ltd. It will be seen from the drawing that the wall units are erected on an *in situ* concrete floor, in which side channels have been formed to receive them. Both wall and roof units are 12 in. wide, and are butted together with a straight joint afterwards pointed up and grouted.

The price of standard Trianco trench units for straight trenching consisting of six wall members and three roof members to 1 yard run works out at £2 8*s.* 3*d.* and assembly for blank end £2 3*s.* complete. Three-way crossing and emergency exit consisting of—

1 special lintol, No. 1	£5 10*s.* per complete assembly.
2 side slabs for exit, No. 3	
2 ,, ,, ,, ,, 10	
1 end slab for exit, No. 9	
1 inclined slab for exit, No. 18	
1 top slab for exit, No. 11	
1 special roof member, No. 6	
1 ,, ,, ,, ,, 7	
2 narrow roof members, No. 19	
5 standard wall members, No. 5	
1 filler piece, No. 16	

Four-way crossing consisting of—

2 lintols, No. 1	£3 4*s.* per complete assembly.
2 special roof members, No. 17	
4 standard roof members, No. 4	

Note.—The above prices are for delivery within a radius of twenty-five miles of works, in full lorry loads, on good hard road adjoining site.

Type N (Fig. 174) is a form of pre-cast sectional trench or

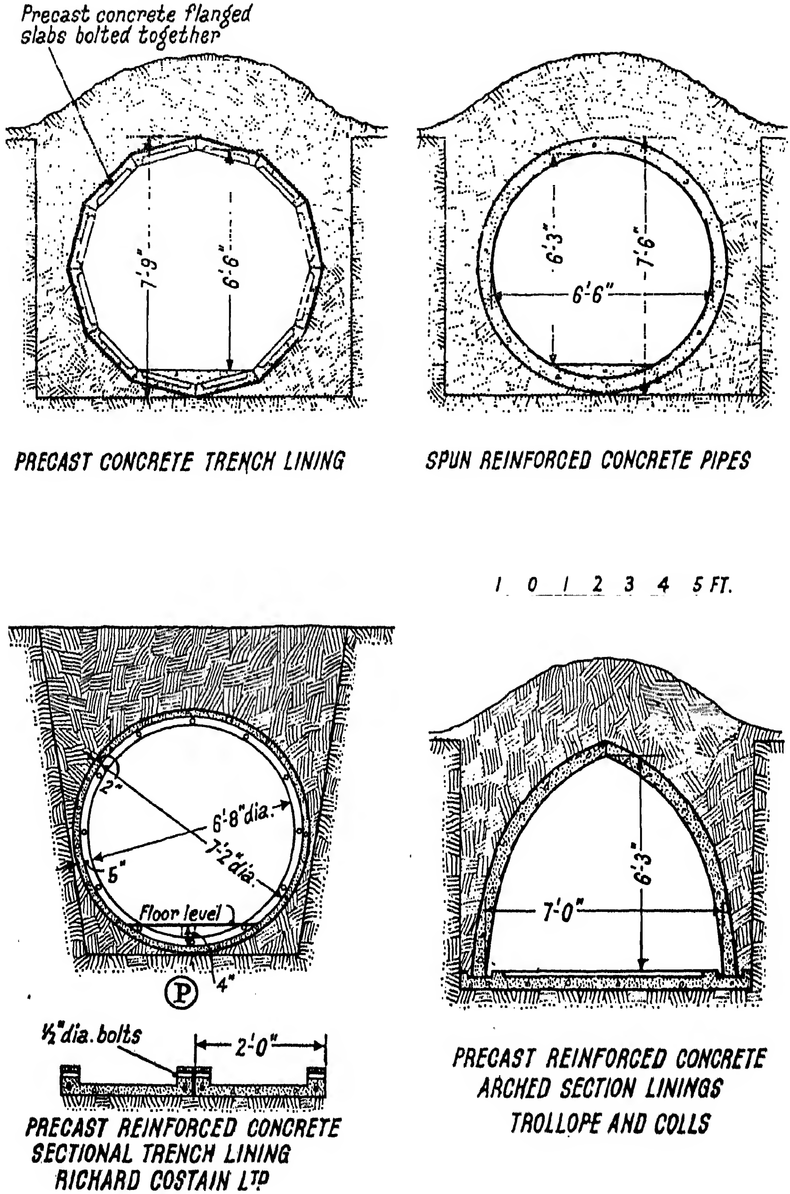


FIG. 174.—Pre-cast trench lining systems.

tunnel lining of very strong design. Its high cost renders its use in trenches prohibitive, but in tunnel work, where there may be little room for the assembly of the lining, the design is particularly suited.

Type O (Fig. 174) comprises spun reinforced concrete pipe sections which with rebated joints form an exceptionally strong trench lining. (See also section on Pipe Shelters.)

Type P (Fig. 174) is constructed of "Shockcrete" segments, designed with a view to the economical construction of deep level bomb-proof shelters.

It is made into a complete circular ring section and can be used at any depth. By means of the special asbestos cord jointing, the shelter can be kept water-tight unless there is excessive external water pressure.

Type Q (Fig. 174). These are pre-cast arched section linings with specially thickened bearing joint at the crown embodying a method of bolting the sections together.

Steel Trench Linings

Fig. 175 shows four typical steel trench linings which, with suitable protection with bituminous coverings, will be found permanent in use and easy to erect.

Type R. This is Costain's locksheet steel lining, also illustrated in Fig. 184 and described in detail on pp. 378 and 380.

Type S. This is constructed of Joseph Westwood & Co.'s steel troughing pressed out on $\frac{1}{8}$ in. thickness metal erected as indicated with the steel clips at the bearings of the roof troughing.

A selection of available sections is given in Table LXXX.

Westwood curved trough sheeting was used during the Great War in the construction of the "baby elephant" shelters. With angle bearings at the base and a steel joist at the crown, semi-circular or "Gothic"-arched sections can be erected with equal facility (see also p. 321).

Type T is the well-known Nissen form of shelter in galvanised corrugated iron protected with a bituminous coating or covered in concrete.

As permanent shuttering to heavy arched concrete shelters it is ideal.

Type U. This shows the vee type interlocking shelter. Each

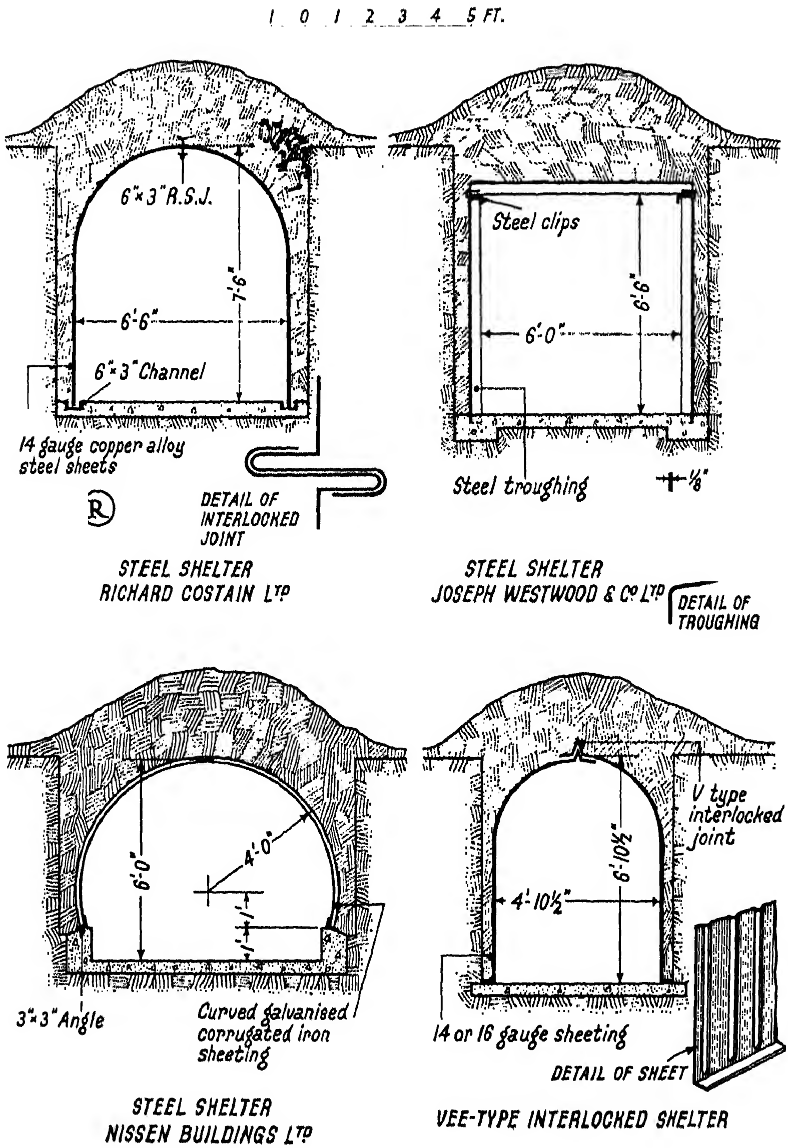


FIG. 175.—Types of steel linings to trenches.

section of a vee type interlocked A.R.P. shelter is hot-dipped in bitumen at the factory, and it is claimed that this ensures from fifteen to twenty years' life for the shelter under normal conditions when the sheeting is covered with ordinary earth.

A special feature of the design is that no bolts or rivets are used in its manufacture or erection. Every sheet or section is interlocked, thus making the connection between the various members a flexible one providing a strong connection at the joints. It is claimed that the flexibility of this particular

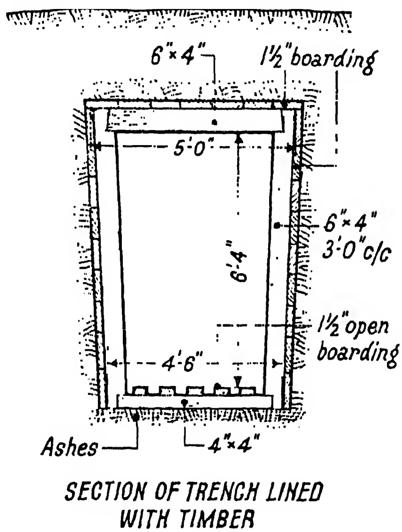


FIG. 176.—V-type trench lined with timber.

shelter renders it especially capable of withstanding all shocks due to uneven loading caused by bombing in the vicinity.

The normal accommodation is three persons per yard run for the shelter as illustrated. In the case of ventilated shelters the capacity can be increased to four per yard run.

Prices per yard run of vee type interlocked shelters for trench linings or shelters are given below for various sizes of shelters and gauges of steel sheets.

	16 gauge sheets.	14 gauge sheets
4 ft. 10½ in. wide × 6 ft. 10½ in. high .	£3 0 0	£3 10 0
7 ft. wide × 6 ft. 9 in. high. . .	£3 7 6	£4 0 0

A shelter 7 ft. by 6 ft. 9 in. by 27 ft. long is assumed to hold fifty-two people. The cost of the rear 3 ft. section, complete with gable end, emergency exit with water-sealed steel cover, steel ladder, together with the front gable and steel door, is £23 10*s*. The total cost of a shelter 27 ft. long using 14 gauge sheets will be £55 10*s*. On a similar basis the cost of a shelter 4 ft. 10½ in. by 6 ft. 10½ in. by 27 ft. using 14 gauge sheets will be £49 10*s*. Without gas-tight entrance and exit steel door and ladder, the total cost for the shelter using 16 gauge sheets can be reduced to £42 10*s*. for the 7 ft. by 27 ft. and £38 for the 4 ft. 10½ in. by 27 ft. shelter.

Type V (Fig. 176) is constructed in timber, using 1½ in. boarding on 6 by 4 in. frames at 3 ft. c/c.

Note the 4 by 4 in. creosoted sleepers laid on ashes and supporting the creosoted " duck " board floor.

The exterior surface of the lining should be creosoted and the interior of the trench lining fire-proofed with paint or other approved treatment.

The tapered section of the trench is important, as otherwise the timbering might come loose in very dry weather.

Type W (Figs. 177 and 178). This is in pre-cast reinforced concrete construction fully described on p. 338.

Type X (Fig. 179). This shows Costain's pre-cast arch section shelter, 7 ft. wide, 6 ft. 6 in. high. Each section is 12 in. wide and has a 1 in. rebated joint on each edge. The reinforcement consists of two ⅜ in. bars per section on each face.

The sections are bedded on an *in situ* concrete base and are grouted together.

Type Y (Fig. 180) shows typical section of *in situ* concrete trench lining, complying with the Home Office A.R.P. Department's specification for the permanent lining of trenches. Temporary timbering to the excavation will usually be required in the execution of work to this form of construction. The approximate quantities are given on the illustration.

The intention is that the existing poling boards should be left in place, and that they should act as the external shuttering. Where the width of the trench between existing poling boards is less than 5 ft. 5 in., the poling boards will have to be taken down in sections from one side, and replaced after the trench

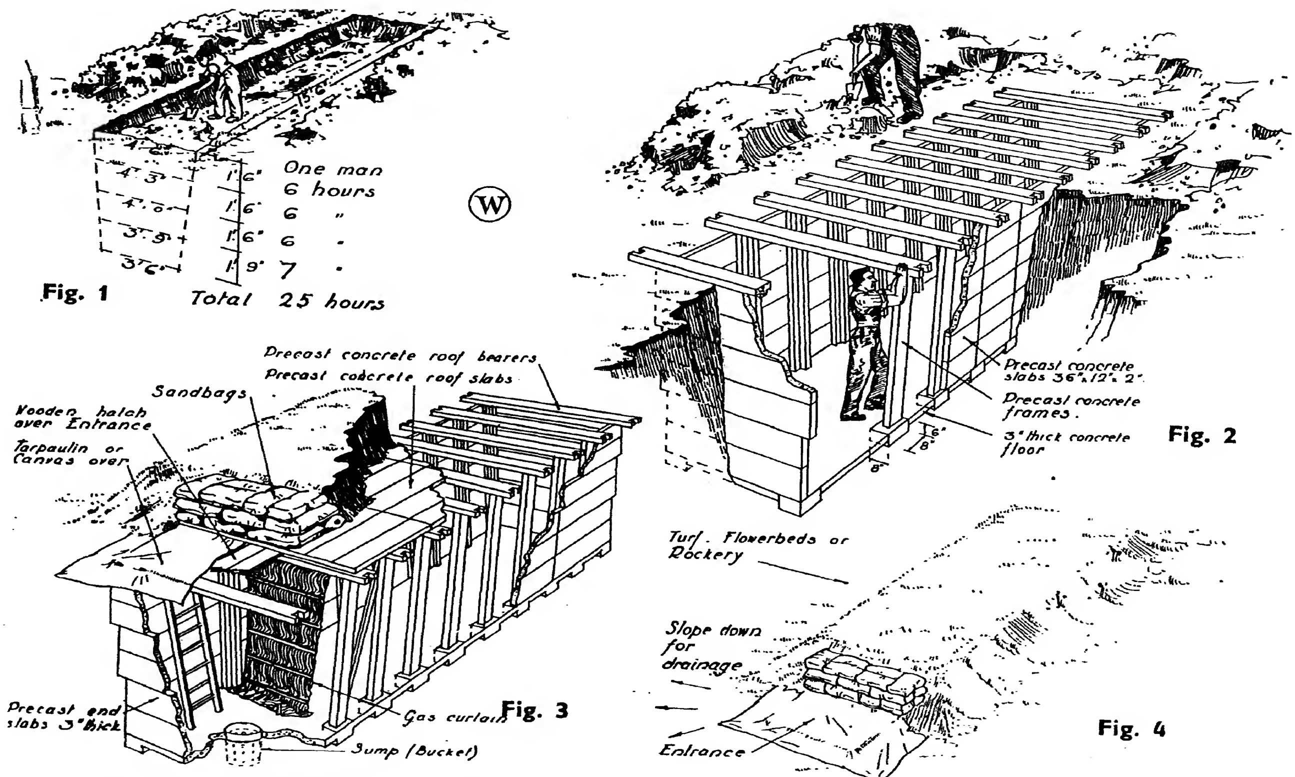


FIG. 177.—Showing method of erection of pre-cast reinforced concrete trench lining for garden shelter.

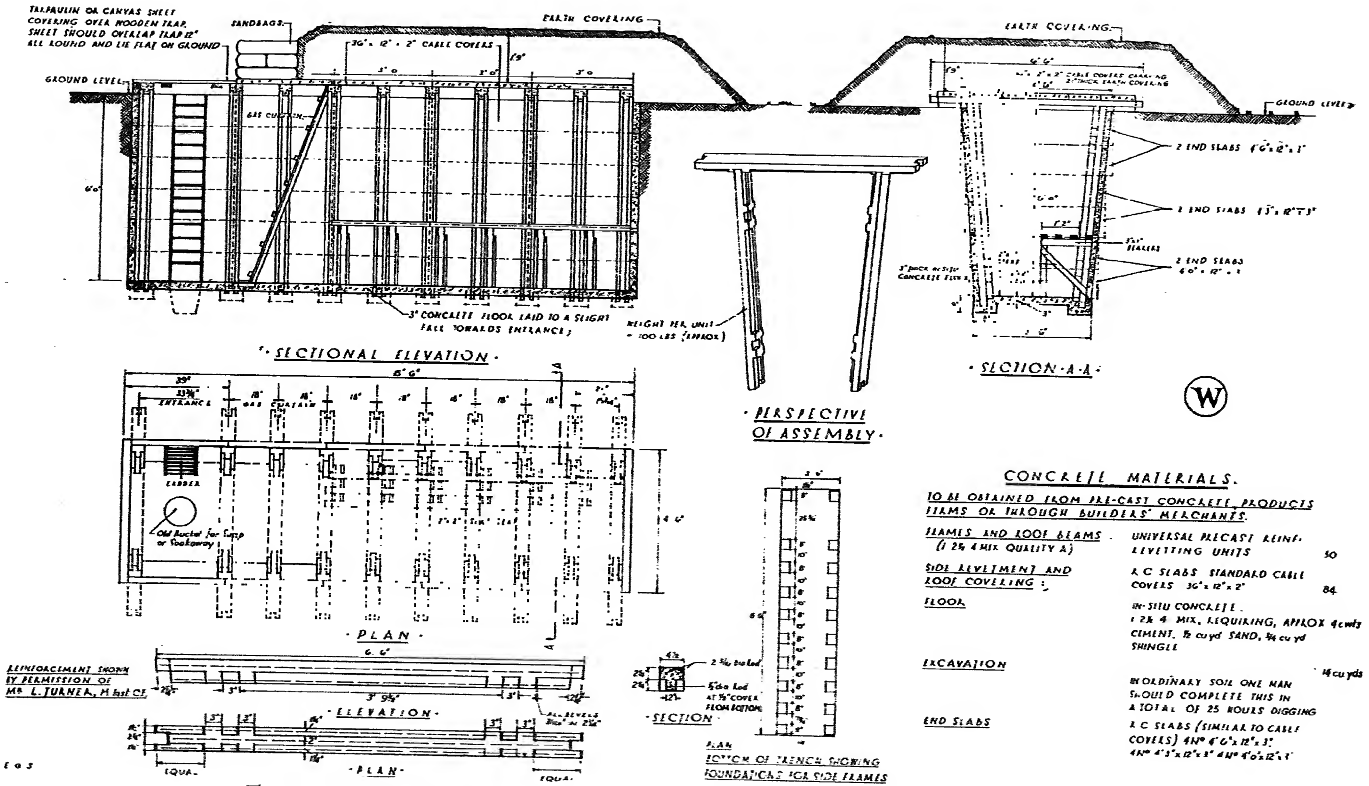


FIG. 178.—Details of pre-cast reinforced concrete lining for trench-type garden shelter.

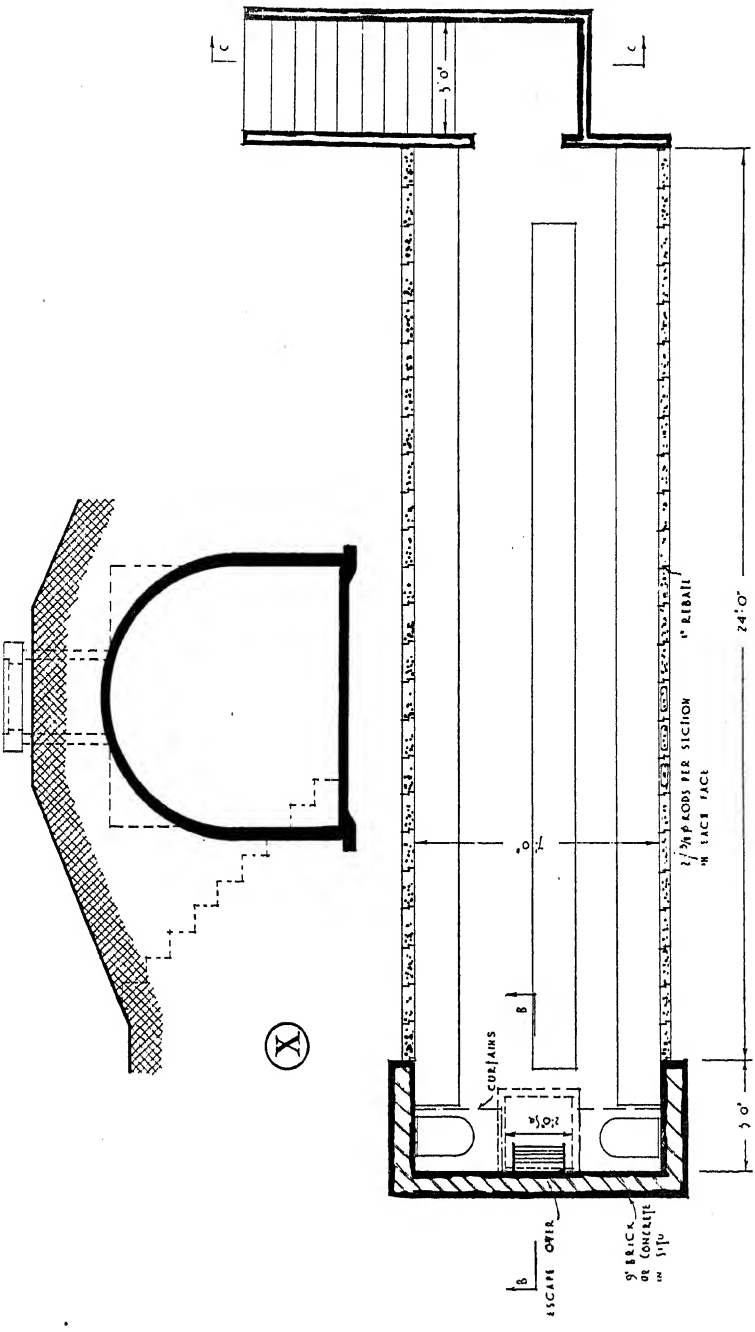
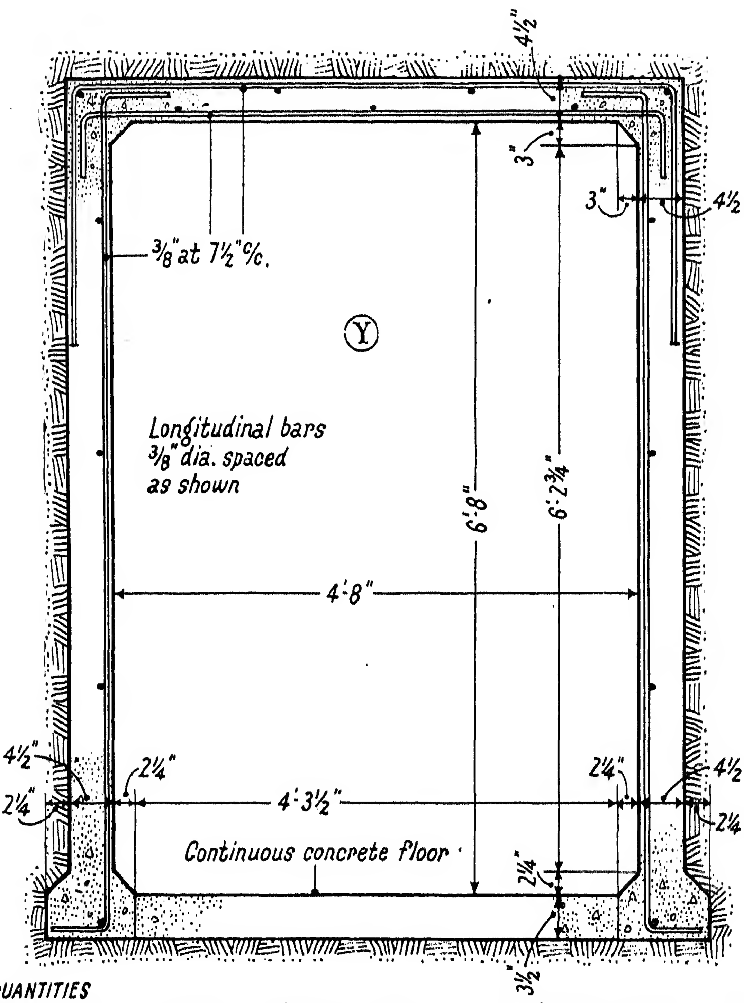


FIG. 179.—Costain's pre-cast arch section trench lining arranged as shelter for fifty persons.



QUANTITIES
In one yard run of trench
of typical section :-
Concrete = 1·0 cu. yds.
M.S. bars = 0·75 cwt.

Note: Concrete mix 1 : 2 : 4 (Ordinary grade or quality)
Cover of concrete to bars = ¾"
Loadings: Roof 450 lb. per sq. ft. (excluding slab)
Walls 100 " " " " at top
250 " " " " at bottom

TYPICAL SECTION THROUGH TRENCH

PLAN No 4778

FIG. 180.—*In situ* reinforced concrete trench lining giving strong monolithic shelter.

has been widened the requisite amount. It is suggested that where site conditions are particularly difficult the simplest course may be to remove all existing timbering and fallen earth from the trench, and concrete in short lengths. In this case external shuttering would, of course, be required; metal shuttering has been devised for this purpose as well as for internal shuttering.

It is probable that a saving in cost could be effected by the use of special types of metal shuttering which lend themselves

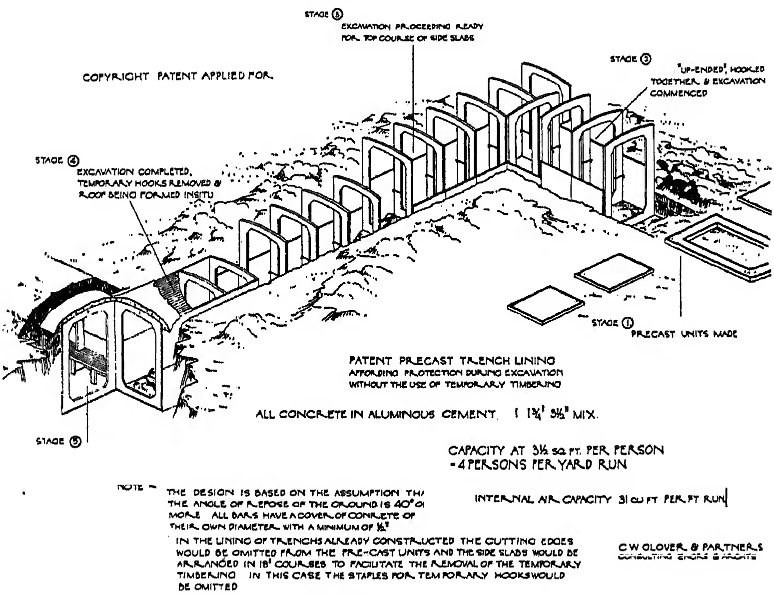


FIG. 181.—Sketch showing method of sinking the Glover rigid frame trench linings *without temporary timbering*.

particularly to the construction of continuous sections, such as trench linings, where the work is repetitive. An alternative which would make for economy is the use of standardised sections of timber shuttering in conjunction with one of the various types of clamps, clips, etc., which are on the market.

The calculations for the type design were based on the "Theorem of Three Moments" and on the stresses defined in the "Code of Practice for Reinforced Concrete"; it should be noted that the Home Office specification permits stresses 25 per cent. greater than the latter.

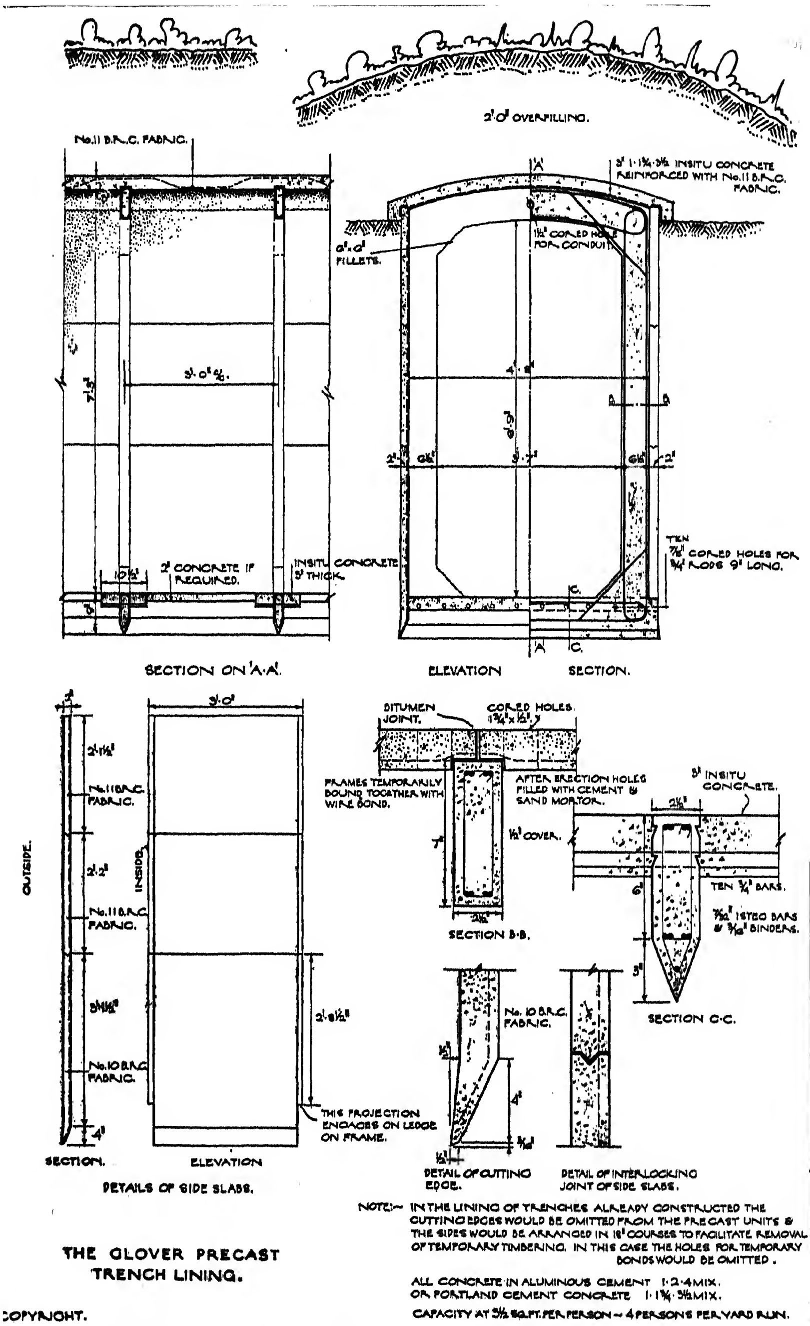


FIG. 182.—Constructional detail of the Glover rigid frame trench lining system.

FIG. 183.—Interior view of the Glover rigid frame R.C. trench shelter.

[*To face page* 376.

Type Z (Figs. 181–183). A rigid frame system sunk into position as the excavation proceeds.

The use of this form of pre-cast trench lining affords protection during excavation *without the use of temporary timbering.*

The design is based upon the latest Home Office requirements and is economical in cost and speedy in execution.

The principle is specially suitable where the ground is of loose or treacherous nature.

The units can be used for the lining of constructed trenches, and by wedging on to the pre-cast frames safety can be assured during the recovery of temporary timbering.

The method of construction is indicated on the sketch reproduced in Fig. 181. The trench is dug to the maximum depth to which it can be safely carried without timber supports. The frames are then up-ended and the side slabs placed in position, being held together temporarily with wire scaffold bonds. The excavation then proceeds within the safety of the protection of the permanent lining until the units are sunk to the correct depth, when the dowels are inserted in the bottom of the frame and the foundation concrete placed.

Construction of the floor and roof then proceeds, and the excavated material banked over the shelter affords, in conjunction with the pre-cast units, Class 5 protection.

The roof is designed for a super load of 400 lb. per sq. ft.,

TABLE XCI

TRENCH LINING UNITS, DELIVERED FREE IN LONDON AREA

Prices

	In Ciment Fondu.	In British Portland Cement.
Reinforced concrete frames	22/6	18/5
Side walling slabs, per run of trench, one complete set of slabs	41/10	35/9
End slabs as above described, per set of three slabs, 5′ wide and 7′ 9″ high	41/10	35/9
If desired, pre-cast reinforced roof sections, 3″ thick, per set for one bay 5′ × 3′ 2″, including 2″ for side rebates .	23/8	19/3
Entrance door frames	16/6	13/3
Pre-cast entrance, stairs and walling complete, per set .	107/10	92/5
Should these be supplied without treads, there would be a reduction in price of	15/6	12/–

the side slabs for 250 lb. per sq. ft. at the bottom and 100 lb. per sq. ft. at the top.

The units are supplied by Universal Floors Ltd., 91 Gower Street.

LOCKSHEET GALLERY SHELTERS

Where large numbers of workers or children, for example, have to be provided for, there are obviously enormous advantages of cost in a well-thought-out trench system which, combined with steel lining, overhead sand-bagging and gas masks, will give protection against everything save direct hits. Careful attention to ventilation and the layout of the trenches in relation to prevailing winds will greatly minimise the risk of the penetration of heavy gases into the steel-lined excavation.

Steel lining frequently consists of locksheet steel sections which curve upwards and lock in the form of an arch, thus making the shelter capable of withstanding high pressure. A special property of locksheet steel is its copper content, which greatly increases its durability, and ensures the permanence of a shelter which might otherwise be subject to rapid deterioration. The average gallery shelter is 7 ft. 6 in. in height and 7 ft. in width, the length varying according to requirements.

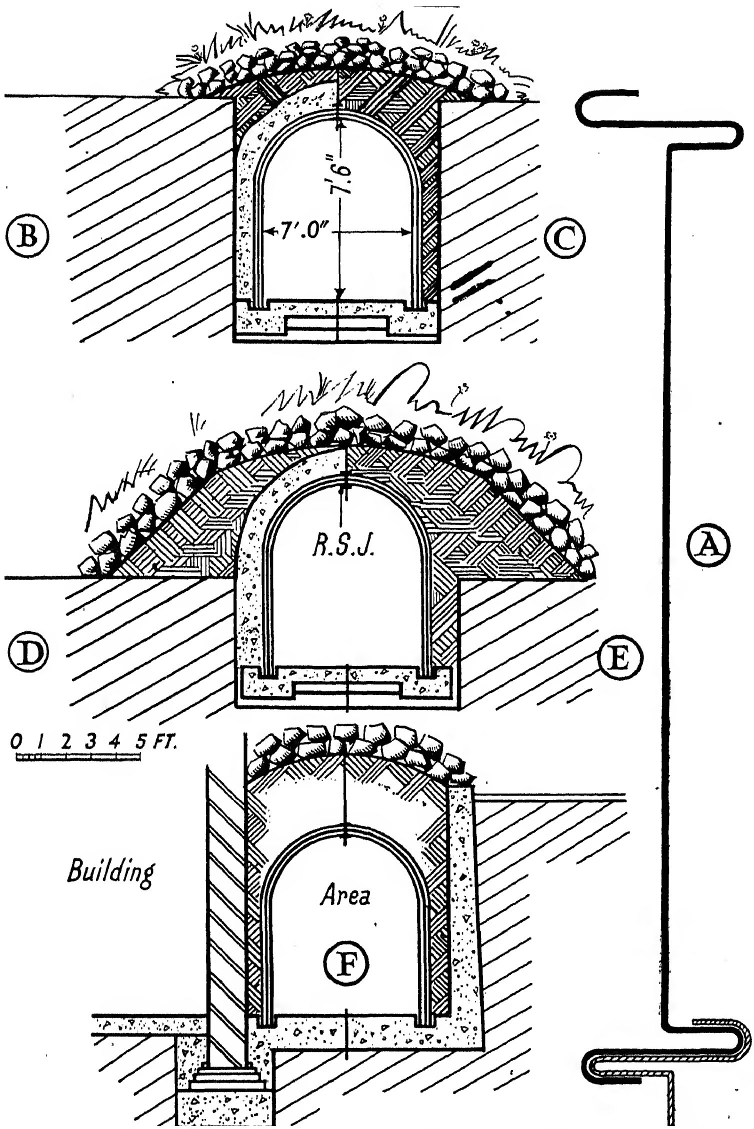
Gallery shelters range from the small type for family use to those accommodating large numbers of people. The latter should, in order to localise the effect of explosions, be planned as a series of refuges, with chambers leading off them, instead of the continuous tunnel type.

Fig. 184 shows various arrangements. A shows the section of the interlocking curved steel sheets, and B–F inclusive, various sections of shelters.

The last-mentioned detail shows a shelter accommodated in an area in front of a building and made splinter-proof by the covering of earth and rubble.

If the building contains heavy cornices and other projections it would be better to cover the shelter with concrete.

The locksheet lining consists of 14 S.W.G. copper alloy steel sheets, bent at the ends to form an interlock and curved in section in the form of an arch.



ALTERNATIVE SECTIONS OF LOCKSHEET STEEL SHELTERS

FIG. 184.—Costain's locksheet steel shelters. A, enlarged section of locksheet steel; B, constructed in deep trench and covered with concrete, earth and rubble; C, constructed in deep trench and covered with earth and rubble; D and E, partly underground, and F, in area of building.

It is made in two sizes :—

(*a*) 7 ft. 0 in. wide × 7 ft. 6 in. high.

(*b*) 13 ft. 0 in. wide × 9 ft. 0 in. high.

in standard lengths of 2 ft. 3 in. Hence shelters may be made of any length in multiples of 2 ft. 3 in.

Shelters may be erected :—

(*a*) In trenches completely under ground.

(*b*) In trenches half under ground.

(*c*) On the ground where there is water in the subsoil.

(*d*) In existing areas or cellars.

(*e*) In tunnels under existing buildings where space is limited.

No bolts or clips are required and erection is easily done by unskilled labour without plant or tools. The bottom of the Locksheet lining sits in a 7 × 3 in. channel and the top on a 7 × 3 in. R.S. joist.

The bending of the edges and the curving of the sheets gives the lining high crushing strength.

The lining is easily transported and handled, and adequate headroom is provided, namely 7 ft. 6 in.

The copper alloy ensures resistance to corrosion.

In an open-ended shelter without an airlock, but with two lavatories, allowing 6 sq. ft. per person as recommended by the Home Office, fifty people can be accommodated in a shelter 51 ft. 9 in. long. Allowing 3½ sq. ft. per person, fifty people can be accommodated in a shelter 31 ft. 6 in. long.

In a closed shelter with an airlock, two lavatories and an air filtration plant, fifty people can be accommodated in a shelter 60 ft. 9 in. long.

In a closed shelter without an air-filtration plant, 3 ft. run, are required per person, equivalent to 75 sq. ft. of total surface area which is the figure recommended by the Home Office.

As a guide in calculating, 0·92 of a running foot is required per person for an open-entrance shelter, to give each occupant 6 sq. ft. of floor space and 0·45 running foot to give each occupant 3½ sq. ft. of floor space—the Home Office minimum. For the larger 13 ft. 0 in. lining these figures should be halved.

The present prices are :—

£5 15*s*. per 2 ft. 3 in. section for the 7 ft × 7 ft. 6 in. lining, and £10 6*s*. 3*d*. per length for the 13 ft. × 9 ft. lining all including R.S.J. and steel channels ex works.

CHAPTER X

COMMUNAL SHELTERS

THE private shelter has been dealt with in Chapter VIII, but gas- and splinter-proof shelters in factories and business premises for communal use will now be considered.

On April 25th, 1939, the Home Office issued a code and a revised one in Aug. 1939 giving regulations for all industrial shelters, including basements and trench linings, which, under the new Act, have to be provided by all concerns employing fifty or more persons. Shelters must be designed in accordance with this code, the main points of which may be briefly summarised as follows :—

1. A shelter should not ordinarily be for more than fifty persons unless provided with traverses or right-angle bends as in trenches.

2. The minimum area necessary for trench shelters, and what is termed the "tunnel" form of shelter, is 3·75 sq. ft. of floor per person (which area includes that required for two closets), but for all other shelters it is 6 sq. ft. per person.

3. There must be one emergency exit to each fifty persons.

4. The minimum height is 6 ft. 6 in.

TABLE XCII

	Load in lb. per sq. ft. on Roof	Wall At Base.	Wall At Top.
(i) *Standard Home Office Minimum* for all public shelters where the shelter is entirely below ground level for soils having an angle of repose of 40 degrees or more (the usual case)	400	250	150
(ii) *Heavy Home Office Maximum* loading for poor soils where the shelter does not exceed 9′ below ground level	400	400	200

5. Loading standards are not laid down for industrial shelters, but they must meet the reasonable requirements of the special factory inspectors or regional technical officers. It is obvious that if a shelter is approved by the Home Office for public use, it is acceptable for factory use.

6. Table XCII gives the Home Office standard loadings to which shelters should be designed with a factor of safety of three on code stresses :

Other Shelters

Official regulations governing the construction of shelters giving Class 5 protection and of a design other than of the tunnel or trench type include, *inter alia*, the following :—

For other shelters wholly or partly below ground level there shall be :—

Not less than 6 sq. ft. of floor area for every person in the shelter ;

Not less than 50 cub. ft. capacity for every person in the shelter ;

Not less than 25 sq. ft. of surface area of walls, floor and roof for every person in the shelter.

(See also revised code, Chapter XII.)

Limits to Number of Persons and Separation of Shelters

In order to minimise the number of casualties likely to result from a direct hit, shelters should not be closer than 25 ft. in any direction, and 40 to 50 ft. spacing is preferable where conditions permit.

Where, owing to restriction of the site available, it is necessary to accommodate parties of more than fifty persons, as in large basements, strong *dividing walls* should be provided *between the parties*. The maximum number in a *party must be limited to* 200, and the dividing walls should be provided under expert advice. As a working rule, the dividing walls should be not less in thickness than twice the thickness of the floor over the shelter if made in reinforced concrete, not less than three times the thickness of the floor over the shelter if made in brickwork or masonry. In no case may the dividing walls be less than 12 in. thick in reinforced concrete, nor less than 13½ in. thick in brickwork or masonry.

It is essential that the dividing walls be much stronger than other parts of the shelter to ensure that in the unhappy event of a direct hit on one side of it relief for the forces of the explosion are found through the roof or side other than the division itself.

At the behest of the Lord Privy Seal an international competition was recently held by the A.R.P. Institute for the design of a fifty-person shelter to be constructed on ground in which the standing water level was 2 ft. below the surface.

The conditions included stipulations that the sides be capable of resisting splinters in accordance with Appendix D in the Home Office Handbook No. 6, and be capable of carrying the roof and roof loads with earth pressures if any. The roof was to be capable of resisting light incendiary bombs, and, if at a slope of less than 30 degrees to the horizontal, the thickness could be taken at not less than half that for the sides determined as above.

The roof was specified to carry a vertical superimposed load of 200 lb. per sq. ft. The shelter had to be designed for fifty persons with the following minimum requirements per person :—

(*a*) Six sq. ft. of floor area if walls are vertical, and if walls not vertical equivalent accommodation to be provided.

(*b*) Twenty-five sq. ft. of combined floor, ceiling and wall area.

(*c*) Fifty cub. ft. of air content.

Provision had to be made for some form of natural cross-n tilation, but artificial ventilation was not required.

The assessors awarded the premium for a design in monolithic inforced concrete octagonal in plan and with a flat roof, as in their judgment it complied more closely to the conditions of the competition than any other submitted, with particular reference to the fact that its cost was the lowest of the twelve selected for final detailed consideration.

A close runner-up was a square plan in reinforced concrete with a dividing wall supporting the roof, the competitor having secured the advantages of pre-cast units without entirely sacrificing the advantages of continuity of reinforcement. Circular plans were commended, but ruled out on considerations of cost.

Ventilation

In the case of public or other collective shelter accommodation mechanical ventilation will be necessary. The ventilating system should be capable of delivering a minimum of 150 cub. ft. of filtered fresh air per person per hour, and should be a "protected" input system in which the following provisions should be made :—

1. Air intake at sufficient height (not less than 30 ft. above street level or 10 ft. above any adjacent roof level), whichever is the higher, to reduce the volume of gas drawn in. Duplicate inlet shafts will give additional protection.

2. Air intake shaft, right up to the fan, of such construction as to be immune from damage by blast, small bombs and splinters. This shaft should be provided with some form of pressure relief to prevent damage to the fan by blast.

3. Ventilating plant adequately protected from damage by direct hits of small bombs and splinters, and situated preferably in the basement of the building, or in that portion of the building which affords the greatest protection against damage by blast, splinters, etc.

The ventilating plant should be manually operated where it is possible to obtain the requisite power by this means. Where the power required is too great for manual operation petrol engine fan drives should be installed in a separate compartment with the exhaust pipe taken to the outside air and protected against damage by blast, splinters and small bombs. The use of electric motive power is not recommended owing to the risk of failure of the public supply.

4. Suitable officially certified gas and dust filter fitted on a by-pass in the discharge side of the fan, and easily replaceable.

5. The filtered air should be admitted at high level and at sufficiently high speed to ensure an induced air circulation in the shelter accommodation itself.

6. Suitable non-return outlets at low level for vitiated air : these outlets should also be protected from damage by bombs and splinters.

7. A special bin should be provided for the storage of used gas-filter canisters.

N.B.—Under all circumstances, *exhaust* ventilating systems should be shut down.

Heating

In the case of public or collective shelters holding up to fifty people, heating will not normally be necessary.

Where it is provided it should be by means of electrically heated apparatus, a supply being taken from the power mains—the risk of the supply being cut off being accepted. It is undesirable to use methods of heating or lighting which consume oxygen or discharge fumes.

Equipment of Shelters

Shelter accommodation should be equipped with the following apparatus :—

1. Dry or chemical closets where ordinary sanitary accommodation is not available. These should preferably be placed in ventilated accommodation off the main shelter.

Two systems of chemical sewage disposal are described on pp. 167 and 169.

2. A storage tank for drinking water.

3. A self-contained wireless set.

4. Controls for electrical apparatus used for ventilating or lighting the shelter.

5. Fire extinguishers.

Containers should be placed in all " air-locks " forming the anteroom to air-raid shelters to receive the outer garments of gas cases.

It is also of vital importance to safeguard foodstuffs from the effects of gas, and for this purpose gas-tight containers are necessary.

The " Solent " container is completely gas- and odour-proof. No rubber, felt or other organic sealing material is employed and the method of closing is entirely independent of levers or bolts, so that maintenance is unnecessary.

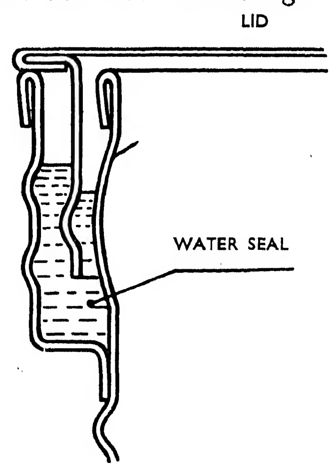


Fig. 185.—Showing type of water seal used in gas-tight containers—exit manholes, etc. made by the Solent Engineering Co.

It will be seen from the illustration (Fig. 185) that the top of the container is provided with a double rim to take the sealing fluid, *e.g.*, water. The lid has a

lip which enters the water and completely seals the container against gas and odour.

The containers are galvanised inside and out as protection against corrosion.

Provision of Shelter Accommodation for Factory Workers

The warning period of an air raid is not likely to be more than seven minutes, so it is undesirable to disperse workers to their homes on receipt of a warning, if they cannot reach their homes within this short period.

It will therefore be necessary to provide shelter protection for the majority of workers in or around the factory buildings.

The form that this protection should take must vary according to the type of factory and the local conditions prevailing.

Where there is open ground adjoining the factory, protection can be provided in the form of trenches, and a system of trenches to accommodate large numbers of workers is described on pp. 334 *et seq.*

Access to Shelters

Whatever type of shelter be adopted, access to it, both at night and in daytime, should be such as to allow of all persons reaching their allotted places within five minutes of an alarm being given.

Exits

All shelters must have two entrances as remote as possible from each other and at least one of them must lead to the open air. All entrances must have adequate lateral protection.

Sanitary Accommodation

One closet seat should be provided for each twenty-five persons with subsidiary buckets and urinal facilities.

Siting of Shelters

Shelters should be below or on the ground, and only under expert advice should industrialists place their shelters on upper floors.

Fig. 186 shows siting as recommended in the code, but each

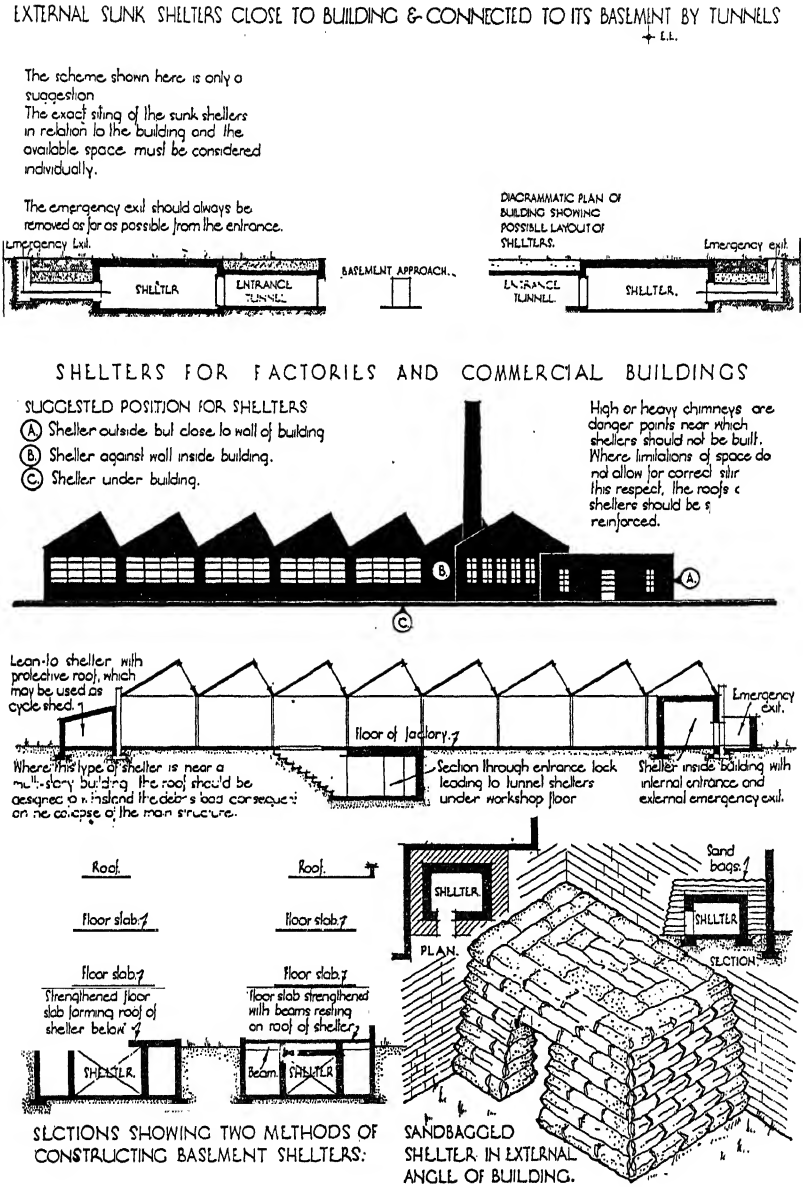


FIG. 186.—The siting of industrial shelters.

Courtesy "The Builder."

group of buildings must be considered separately, there being no hard and fast rules to apply in all cases.

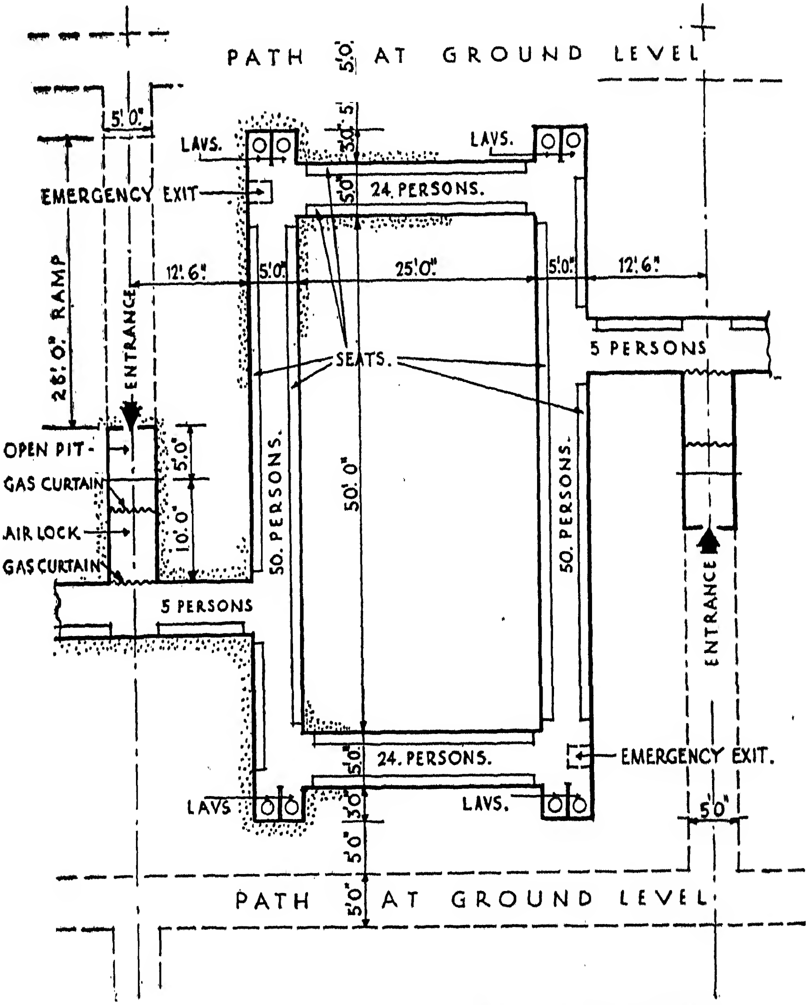


FIG. 187.—Section of block trench planning giving accommodation for 1,200 persons to the acre.

The approved methods for the protection of personnel may be summarised as below :—

A. The provision of isolated shelters exterior to the buildings, as in

1. Blockhouse shelters.
2. Covered trenches.
or 3. Tunnel shelters.

B. The provision of shelters within the buildings.
   (i) Trenches or tunnels under lowest floor.
   (ii) Strengthened basements.
   (iii) Strengthened ground floor rooms.
   (iv) Specially built shelters within or adjoining the existing buildings.

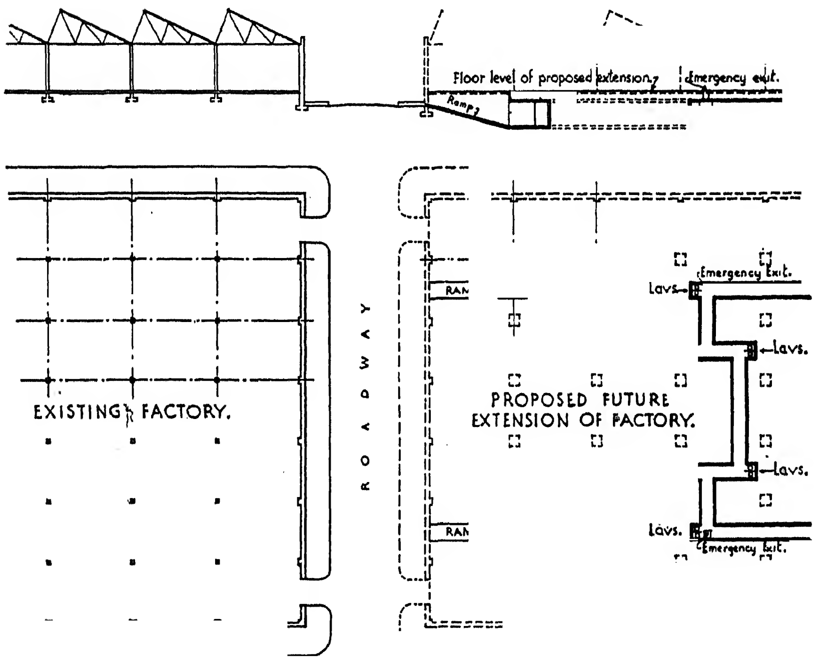


FIG. 188.—Showing planning of trenches adjoining factory to allow of future extension of the premises.

C. Special shelters for key personnel.
   a Key men tending vital plant.
   b A.R.P. personnel.

A. Isolated Shelters Exterior to Buildings

They should be near the usual place of occupation of the personnel for whom they are intended.

They should be a safe distance from tall buildings—chimneys, water towers, etc.—usually half the height distant.

They should preferably be on high well-drained ground.

Trenches arranged as shown in Fig. 187 can be constructed to accommodate as many as 1,200 persons to the acre.

An independent arrangement of trench shelters each to accommodate fifty persons and arranged so that the shelters are spaced at least 25 ft. apart in any direction is shown in Fig. 133.

When constructing trench shelters in the open adjoining a factory, the possible extension of the buildings must not be overlooked and the trenches planned to accommodate it generally as indicated in Fig. 188. See also section on Tunnel Shelters.

B. Shelters Within Buildings

It is evident that situations at which there are unavoidable sources of danger should not be chosen for the accommodation of shelters, but Figs. 189 and 190 show suggestions for the provision of shelters within buildings of various types.

The general requirements are as below :—

(*a*) In cases where services passing through or near shelters constitute a potential source of danger, the hazardous services should be diverted.

(*b*) Openings of emergency exits should be outside buildings and as far from them as possible in order to reduce risk of blocking. The distance should be at least half the height of the building, or additional emergency exits will need to be constructed.

(*c*) There must be at least one emergency exit in addition to the normal entrances to each party of 200 persons.

(*d*) All doors to entrances and exits should open inwards.

(*e*) A selection of tools—shovel, pick and crowbars—should be kept in each shelter, so that, if necessary, occupants can dig their way out.

(*f*) The provision of an approved form of emergency lighting in shelters is obligatory.

(*g*) The widths of entrances should be calculated on the basis of 1 ft. for each fifty persons. Minimum 2 ft. 6 in.

(*h*) Shelters need not be gas-proof, but must be so con-

structed as to be capable of being made gas-proof quickly in an emergency.

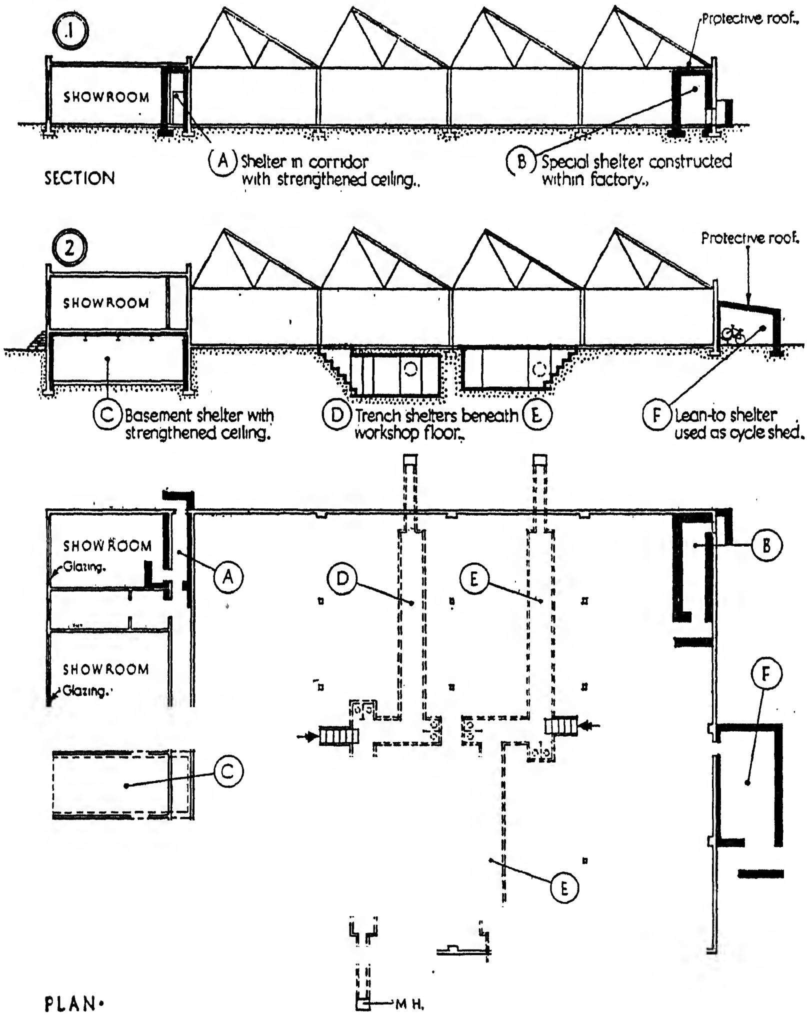


FIG. 189.—Suggestions for the provision of shelters in single-storey factory buildings.

C. Special Shelters for Key Personnel

1. Shelters for fire squads, demolition parties, control centres, etc., can be constructed on the principles already discussed for the family type of shelter.

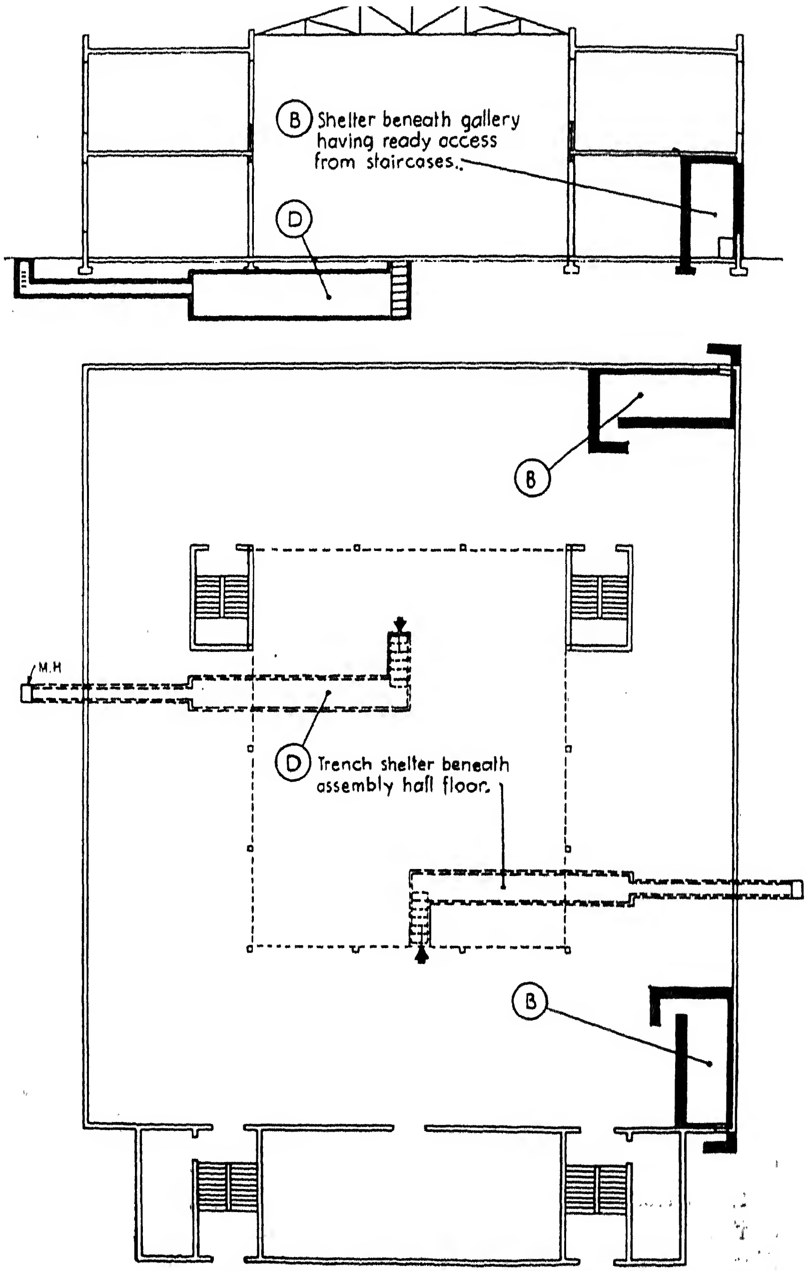


FIG. 190.—Suggestions for the provision of shelters in large workshops.

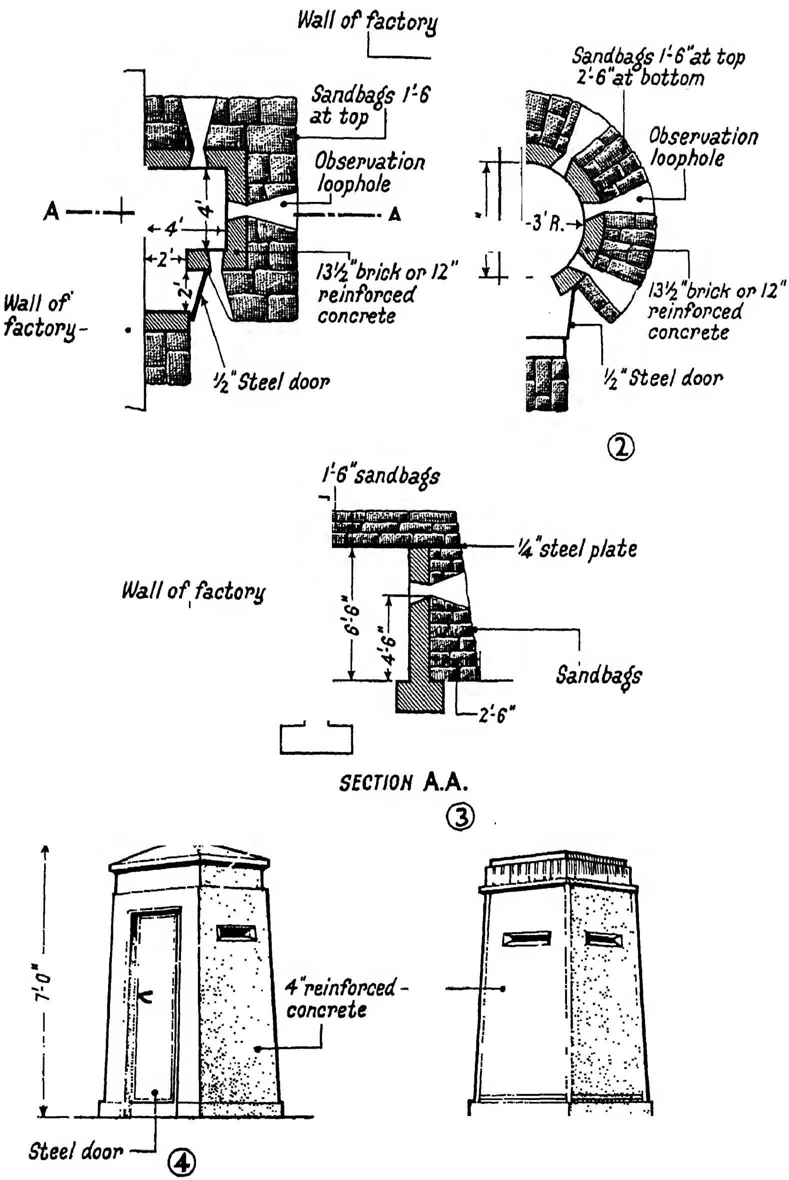


FIG. 191.—Showing alternative designs for individual protected look-out posts.

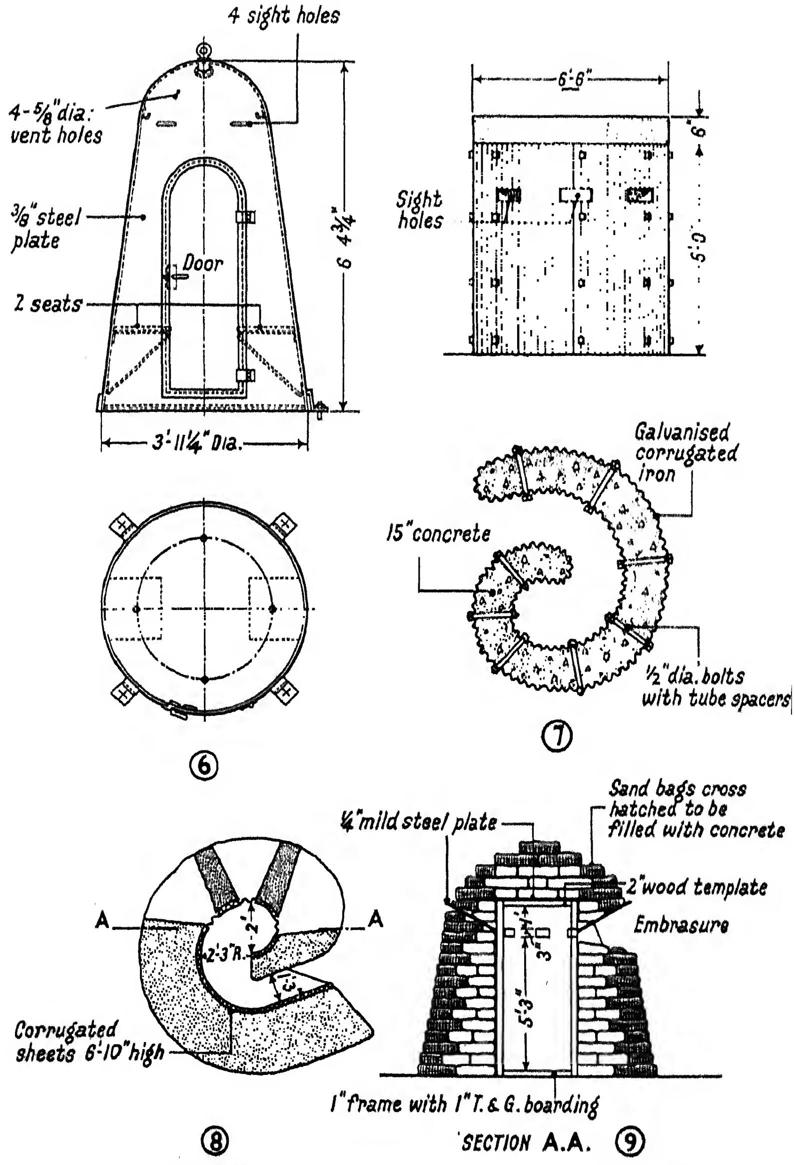


FIG. 192.—Showing alternative designs for individual protected look-out posts.

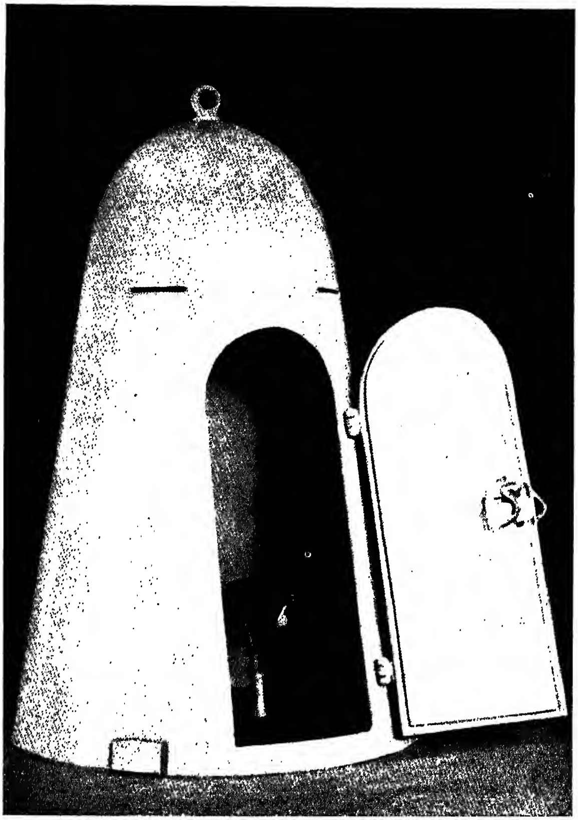


FIG. 193.—Type of heavy pressed steel portable shelter providing shelter for key personnel unable to leave their posts—Solent Engineering Company.

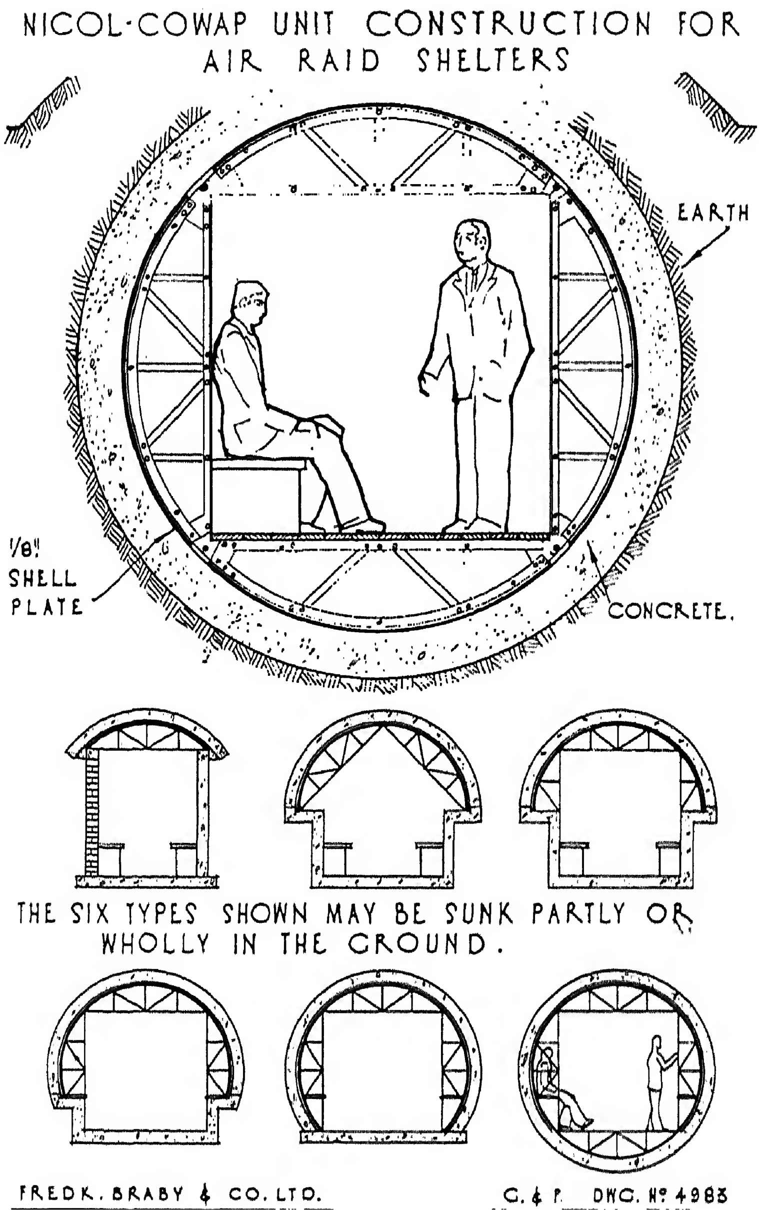


FIG. 193A.—Unit steel construction adapted to structural A.R.P. purposes.

2. Shelters for fire watchers, lookout posts, etc., may be constructed in a variety of ways.

Figs. 191 and 192 show nine alternative designs. Nos. 1, 2 and 3 refer to brick-built posts arranged against the walls of the factory with a steel plate roof and sand-bagged protection. They are suitable for three men and the estimated cost works out to £28 each post.

Illustrations 4 and 5 show reinforced concrete free standing shelters having steel doors and embrasures on three sides. They are suitable for peace-time use as stores for paint or similar inflammable material, and in war-time can be occupied at short notice, additional protection being secured on the outside by the use of sand-bagging.

The estimated cost of each of these shelters, finished in "Cullamix" Scrapecrete rendering, is £40 each.

Illustration No. 6, Fig. 192, shows the Consol portable shelter.

A type of two-or-four-man portable shelter which may be stored at a convenient point and moved to the "active station" at very short notice is illustrated in Fig. 193.

It consists of a steel "strong-point" adequate to resist blast, splinter and bullet risk or a direct hit of an incendiary bomb, yet it is light enough to be transported on a lorry or railway truck without difficulty.

The conical steel chamber is provided with an entrance door, emergency exit, seating accommodation, observation openings giving an adequate field of vision and lifting attachments. The lower edge of the door opening is raised above ground level to prevent the ingress of heavy gases.

The structure is anchored to the ground or floor by $1\frac{1}{8}$-in. foundation bolts passing through holes in the base or anchor plates outside.

A strong eye at the apex facilitates transport and erection by crane or block and tackle.

The weight per unit is approximately 16 cwt. for the four-man shelter and 12 cwt. for the two-man shelter. The costs being £78 and £57 10*s*. each respectively.

Illustration No. 7 shows a type of shelter which can be constructed at a cost not exceeding £25, whilst illustrations 8 and 9 show a similar type constructed with corrugated iron,

sand-bags and steel plates. If the outside layer of sand-bags be filled with concrete, the durability of the whole arrangement will be much improved.

The cost of this type of protective post is approximately £35.

Factories with Multi-storey Buildings

If basements exist, these should first be considered, special attention being paid to :—

(*a*) Strength of ground floor.

(*b*) Safeguarding against flooding.

(*c*) Protection of windows, if any.

(*d*) Protection against gas.

(*e*) The number of persons the basements will hold.

If very heavy machinery is situated on the floors above, the basement should not be used as a shelter.

The basement will probably not take all the workers, bearing in mind the rules for ventilation and the principle of dispersion.

The remainder of the operatives can usually be accommodated in one or more of the following ways :—

(*a*) In trenches, or in shelters above ground where open ground exists.

(*b*) On the ground floor of the building if it can be protected against splinters and gas.

(*c*) Staircases often make good vertical shelters.

(*d*) On the upper floors of the building, the previous recommendation as to the height of the floor, and the number of floors over it being considered on the principles already described.

(*e*) Lean-to shelters built of splinter-proof material against boundary walls, factory building walls, etc.

(*f*) Many small subsidiary buildings are often capable of being converted into shelter accommodation.

(*g*) Small shelters can often be built above ground in odd corners of the works. See Fig. 186.

(*h*) Workers who live near by may be dispersed to their homes.

(*i*) Adjoining factories may have better facilities, and may be able to help their neighbours.

Factories consisting of One-storey Buildings with Roofs of Light Construction, usually mostly of Glass

This is the most common type of factory building, and it should be vacated in an air raid, as it gives no protection at all.

If open ground exists, trenches or above-ground shelters are recommended.

If there is no open ground, lean-to shelters can be built against existing walls.

If floor space can be sacrificed, shelters may be erected inside the buildings, or built as lean-to shelters against the walls on the inside.

Some workers may be dispersed to their homes, and it is often possible to erect small shelters in odd corners of the works, to make use of small subsidiary buildings, or to get help from adjoining factories.

Protection of Personnel Generally

It must be realised that some factories have much better facilities for protection than others, but if each factory is carefully examined, it will usually be possible to find some form of protection for the operatives on the above-mentioned lines. In this connection it should be borne in mind that protection of a low order is better than no protection at all.

Protection for A.R.P. Services in Factories

The various small parties who will have to remain on duty during an air raid will require local protection apart from the general shelter accommodation. This should take the form of small shelters to take the requisite number of persons, constructed in the corners of buildings, or other advantageous localities, at the places where these parties are to be stationed.

Respirators will give gas protection for these parties, but it is advisable to give them overhead protection against any *débris* which may fall on to the shelter.

Structural Protection of Factory Buildings

Generally speaking, the wholesale structural protection for the main buildings of factories is out of the question. Special key points, such as power houses, electric sub-stations, pumping

stations, telephone rooms, etc., the maintenance of which is of vital importance, should, however, be considered.

Such points can usually be protected against blast and splinters, and where the existing roof is vulnerable to the light incendiary bomb it is often possible to provide local protection within the building which will prevent such bombs from actually falling on to important machinery, etc.

Certain buildings, or parts of buildings, can often be protected against splinters and gas for use as shelters for personnel, and such provision will, of course, provide protection to the part so treated. In general the protection of the buildings and plant cannot be achieved by structural, or improvised structural methods, but can be best provided by the various A.R.P. Services, such as the fire-fighting parties as described in A.R.P. Handbook No. 6.

Provision of Shelter Accommodation in Multi-Storey Buildings

Fig. 194 shows various arrangements of basement shelters as recommended in the Code issued under the Civil Defence Act. Attention is directed to the means of entry to and exit from the shelters provided and also to the fact that in the typical example of a large basement used for shelter accommodation the basement under the pavement light is not utilised for shelter purposes. Such pavement lights are a source of danger and normally require strutting up and covering with sandbags to deal with demolition loads.

Fig. 195 shows suggestions for shelters in a typical mill building which having load-bearing masonry walls and timber floors on beams carried on interior cast-iron columns would be unable to withstand serious shock and would be in danger of complete collapse if hit by a bomb. Experience has shown that blast alone may cause considerable damage to such buildings and the earth tremors which accompany nearby bomb explosions have been known to displace supporting columns to such an extent that demolition of the building results. The best form of shelter within such a building where soil and foundation conditions permit would probably be in the form of a tunnel type of shelter as shown at " D " in the figure. Such a tunnel should be continuous throughout the

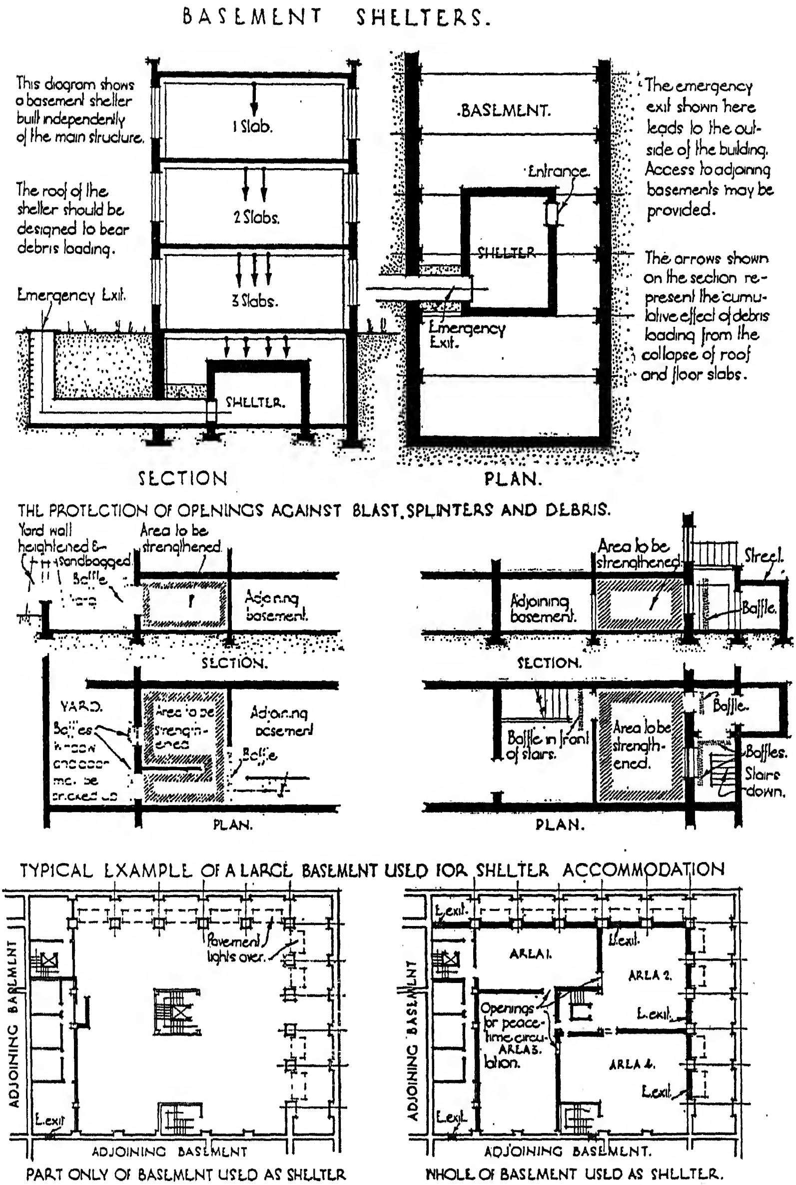


FIG. 194.—Basement shelters as recommended in the Code.

Courtesy "The Builder."

length of the building with exits at both ends preferably leading to the open air. The roofed-in type of shelter shown at " B " in the figure would need to be strengthened to resist the very heavy demolition loads which are to be expected under a building of this type.

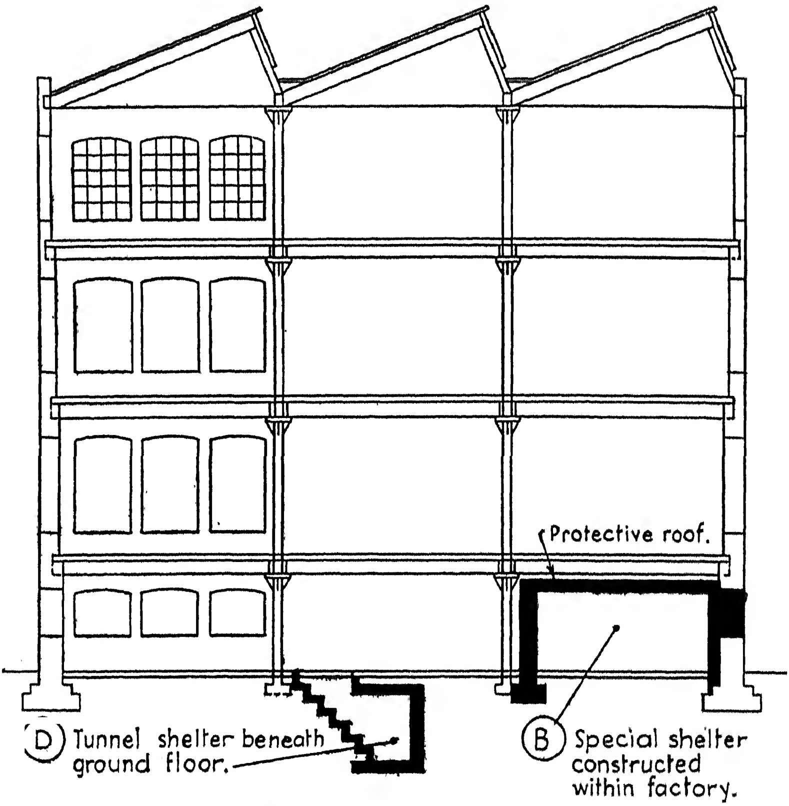


FIG. 195.—Suggestions for shelters in mill-type buildings.

Fig. 196 shows suggestions for the provision of shelters in frame buildings of the warehouse type. Such framed buildings in monolithic reinforced concrete or in steel framing offer considerable resistance to shock and to direct hits. With additional strutting to ceiling and partitions to give lateral protection, the inner rooms on the ground floor and basement can usually be made into suitable air raid shelters provided adequate means of escape are available. It is difficult to

generalise on the subject as each individual case must be dealt with on its merits, but as a rule it may be taken that in a well-constructed frame building the best place for the shelter is in the middle of the ground floor or basement, whereas in unframed buildings the shelters should be near the external wall.

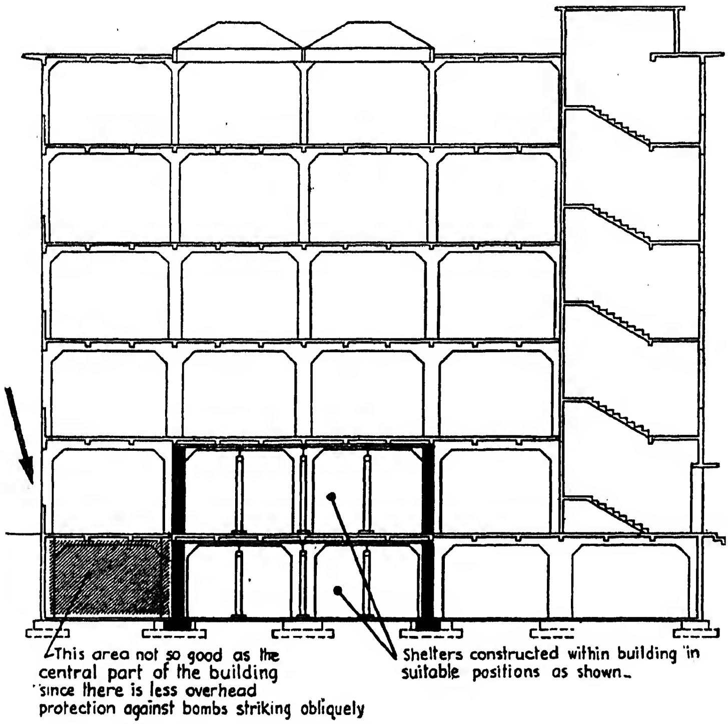


FIG. 196.—Suggestions for the provision of shelters in framed warehouse building.

SHELTERS IN SIDES OF HILLS, SLAG HEAPS, ETC.

If there is a steep hillside, waste dump or slag heap available near enough to be reached within seven to ten minutes, shelters may be formed by constructing galleries. These afford excellent protection, not only from splinters, blast, etc., but also to some extent from direct hits, depending on the amount of earth overhead.

On pp. 378 to 380 information is given concerning the design and construction of galleries incorporating sheet-steel lining

frames; another type is however illustrated in Fig. 197. A method of construction which is simpler, and more permanent, is to use pre-cast concrete tubes of 72 in. or 78 in. internal diameter, with ogee joints, and insert them into the hillside by "jacking" as shown in Fig. 198. This process, say the Cement and Concrete Association, is often followed in U.S.A. for the installation of pre-cast concrete tube culverts under embankments. A trench is dug in the face of the slope so as to enable the first concrete tube to be positioned at the correct level on a timber cradle, with the end of the tube against the vertical face of the excavation. Behind the tube a timber bulkhead is placed so as to enable jacks to convey a horizontal concentric thrust on the tube, support for the jacks being derived from a timber abutment at the rear. Men working inside the tube excavate the earth ahead to a diameter slightly larger than that of the outside of the tube, and to a distance not exceeding the full travel of the jacks. No protection for the leading edge of the tube is therefore necessary and the jacking operation, merely consists in sliding the tube forward. As soon as the first tube has been moved forward its own length a follow-up tube is placed behind it, both then being jacked forward together. The operation is continued until the required length of tube has been placed. Lengths exceeding 100 ft. of large diameter concrete tube have been successfully jacked into position in this way. Any tendency for water to percolate through the joints can be met by inserting bituminous jointing between the pipes before jacking. The construction of a blank concrete wall at the inner end, and of gas-lock doors, etc., at the entrance presents no difficulties and follows the principles already described.

Alternatively the concrete tubes can be placed in position at ground level on the site of a proposed slag heap or dumping ground, leaving them to become covered by degrees as the heap is formed.

This forms an excellent series of gallery shelters in course of time.

Shops and Offices

Large blocks of buildings require special attention in order to reduce interruption of essential services to a minimum.

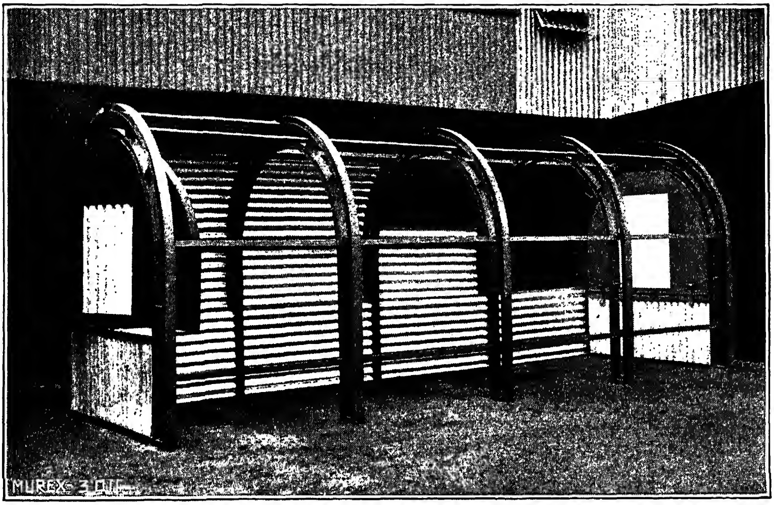


FIG. 197.—Steel framework for arched gallery shelters electric arc welded by Messrs. Connies & Meadow Ltd., Cardiff.

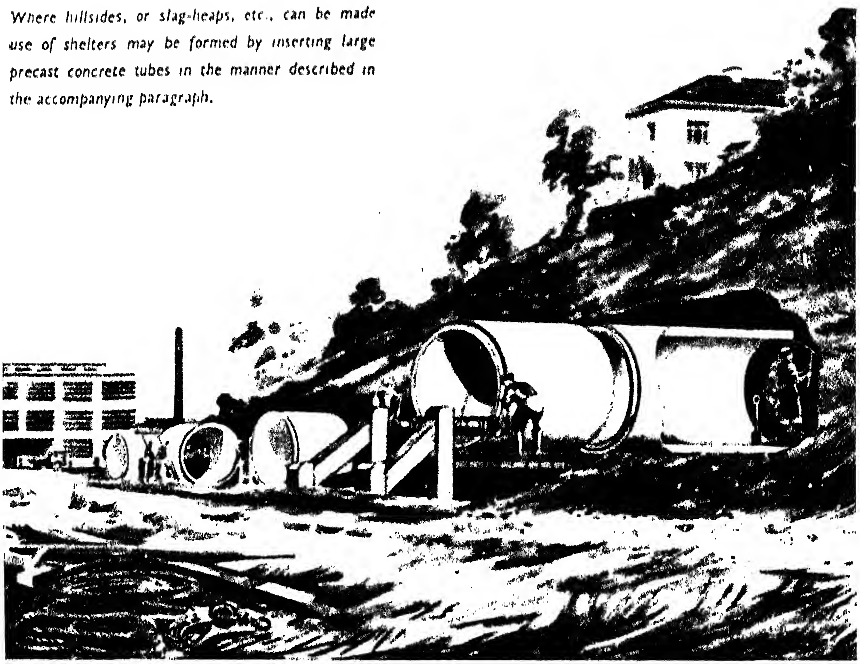
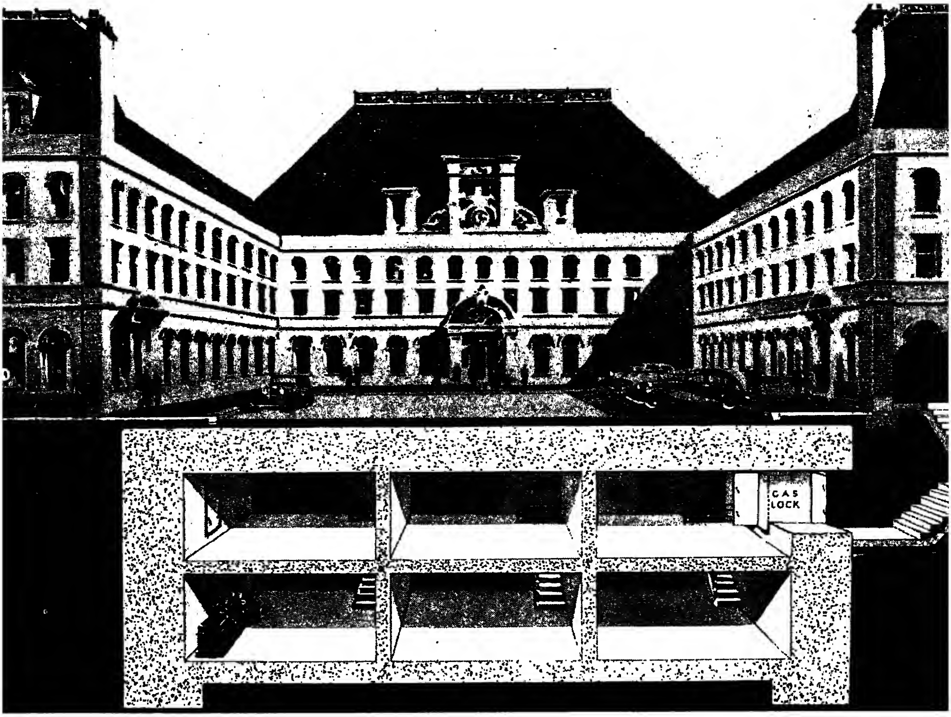
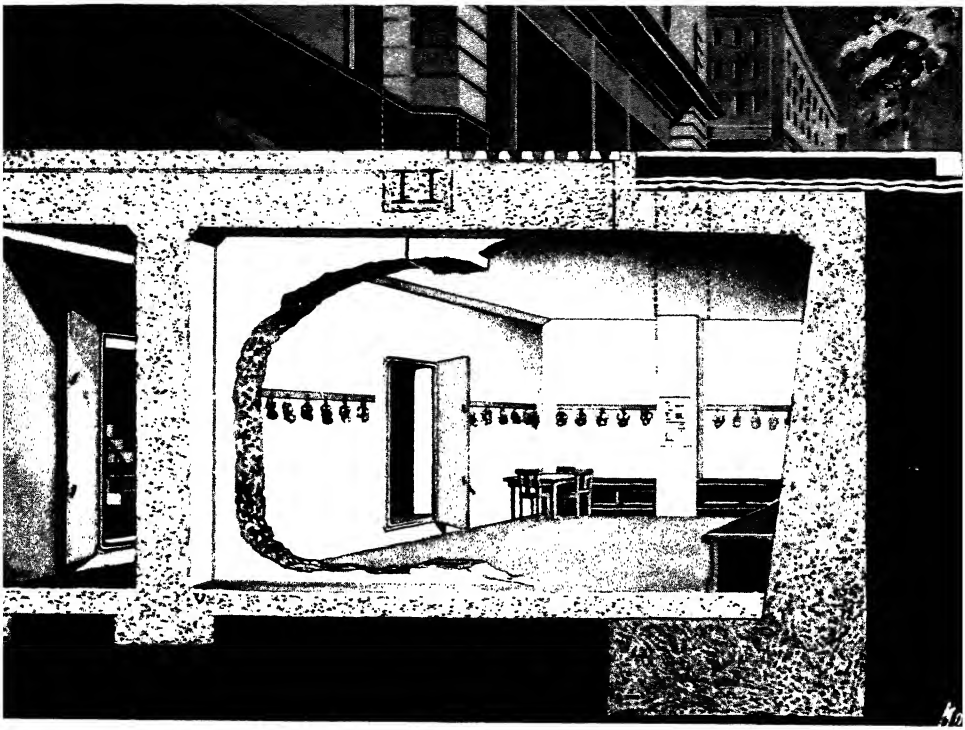


FIG. 198.—Jacking concrete tube shelters into a hillside.



Typical of a bomb-proof shelter to accommodate the working staff of important building
om each compartment must be provided.



Shelter to accommodate staff of large store building—partly under the building and partly unde side-walk.

This applies particularly to the Civic Government Bodies and the Imperial Government Offices, the whole of the staffs of which should have suitably protected accommodation as near as possible to their place of work. Fig. 199 shows a suitable arrangement in which a bombproof shelter is constructed in the courtyard of a building.

The Hotel de Ville in Paris has been provided with such a shelter. The building is a large stone one enclosing a courtyard measuring about 80 ft. square and the shelter is primarily for the accommodation of the administrative staff of the municipality and is not in any sense a public air-raid shelter.

The available net floor space is 3,860 sq. ft., of which 34½ per cent. is taken up by power units, ventilating plant, telephone exchange, lavatories, etc.; thus 7¼ sq. ft. of floor space is allotted to each of the staff of 350 persons it is intended should be housed there if necessary for weeks on end carrying on their duties in an emergency. The shelter is constructed in reinforced concrete water-proofed by asphalt "tanking" placed externally to the concrete. As a "cut and cover" structure, it was completed in three months at a cost of £17,000 or £50 per person accommodated. The roof is 5 ft. 6 in. thick and is close up under the paving of the courtyard. It is reinforced top and bottom with a heavy grid of bars but is not provided with grids at close intervals as indicated at A in Fig. 69, as it was thought that such an arrangement of reinforcement would interfere with the placing of the concrete.

The side walls are constructed close up against the foundation walls of the main building and are therefore reduced to a thickness of about 4 ft.

Because of the protection afforded by the building itself the side walls of the shelter are not carried down to the depths recommended for shelters in the open (see Fig. 222).

The floor of the shelter consists of a mat of concrete about 3 in. thick overlaid with asphalt and upon which the 2 ft. 7 in. reinforced concrete floor is constructed. An air space for ventilator trunking, pipes and cables is provided by the construction of a thin reinforced concrete floor surface suspended above it.

Party walls within the shelter dividing it into approximately eight sections are of reinforced concrete about 2 ft. thick.

They are treated as load-bearing walls and are reinforced and made monolithic with the roof.

There are two large entrances provided with heavy splinter-proof, blast-resisting gas and watertight doors provided with multiple wedge locking devices which can be operated by screw handle from each side.

The ventilation and air filtration plant is of the Schneider-Poelman manufacture and is in duplicate—electrically driven from self-contained generating plant housed underground and provided with means for manual operation. The plant is supplemented by an oxygen-bottle regeneration plant for use in the unlikely event of both ventilation plants being put out of action.

An independent artesian well supply of water from a deep well electric pump is provided and a separate sewage lift operates the drainage from lavatories and toilets.

Complete self-contained telephone and wireless installations make this shelter as nearly as possible an impregnable unit in the essential services of the Civic Government of the City.

A type of shelter suitable for the staff of large stores is shown in Fig. 200. Details will be evident from the illustration, and from what has already been said regarding walls and floor thicknesses the degree of protection can be designed to suit the requirements. In all such shelters it is advisable to limit the number of occupants to fifty in each compartment, which should be self-contained with its own equipment as complete as it is possible to make it. In existing shelters of a similar nature on the Continent independent water supplies from artesian wells sunk through the floor of the shelter are in use in addition to small generating plants for electric lights and battery-operated pilot lights. Luminous paint is used for all the notices so that in the event of the complete failure of the lighting system movement through the various passages can be controlled.

The author has been privileged to visit a number of official shelters of this kind, but for obvious reasons details cannot be published. Suffice it to say that these are all designed generally upon the principles already given and are as a rule completely self-contained and entirely independent of the normal electric lighting, power, water and drainage services.

SHELTER ACCOMMODATION CONSTRUCTED IN THE OPEN

1. Shelters can be constructed in the open, and this form of construction is of particular use in protecting personnel employed in factories, etc., where the buildings are unsuitable for adaptation to provide shelter accommodation.

2. Such shelters may be in the form of trenches, which are described in Chapter IX, or may be built partially or entirely above ground if the land is waterlogged.

3. The general principles governing the provision of shelter accommodation should be applied, and the accommodation should be situated as far as possible from buildings in order to obviate risk from falling *débris*. They should be constructed, if possible, on elevated ground to avoid the possibility of flooding and the collection of gas.

4. Where the risk of falling *débris* is not serious, as in the case of one-storeyed buildings, lean-to shelter accommodation built against the wall of the building may be considered.

5. One advantage of these types of independent shelters is that in normal times they can be used as stores, cycle sheds, etc.

Trench Type Shelters.

Fig. 203 shows a brick-lined shelter which it is claimed can be constructed quickly and economically, providing a permanent form of shelter.

Fig. 179 illustrates Costain's pre-cast reinforced concrete air raid shelter for 50 persons. Pre-cast reinforced type concrete trench sections permit rapid construction of permanent air raid shelters by unskilled labour. Units may be built above ground, partially submerged or below ground to required depth.

The shelter illustrated has been designed according to Air Ministry recommendations to accommodate 50 persons. The pre-cast sections are provided with a special rebated joint which enables the shelter to be rendered reasonably free from surface water drainage at economical cost.

Cost

Supply 24 lineal ft. pre-cast reinforced concrete sections, as shown on the drawing, *ex* works £27 12s.

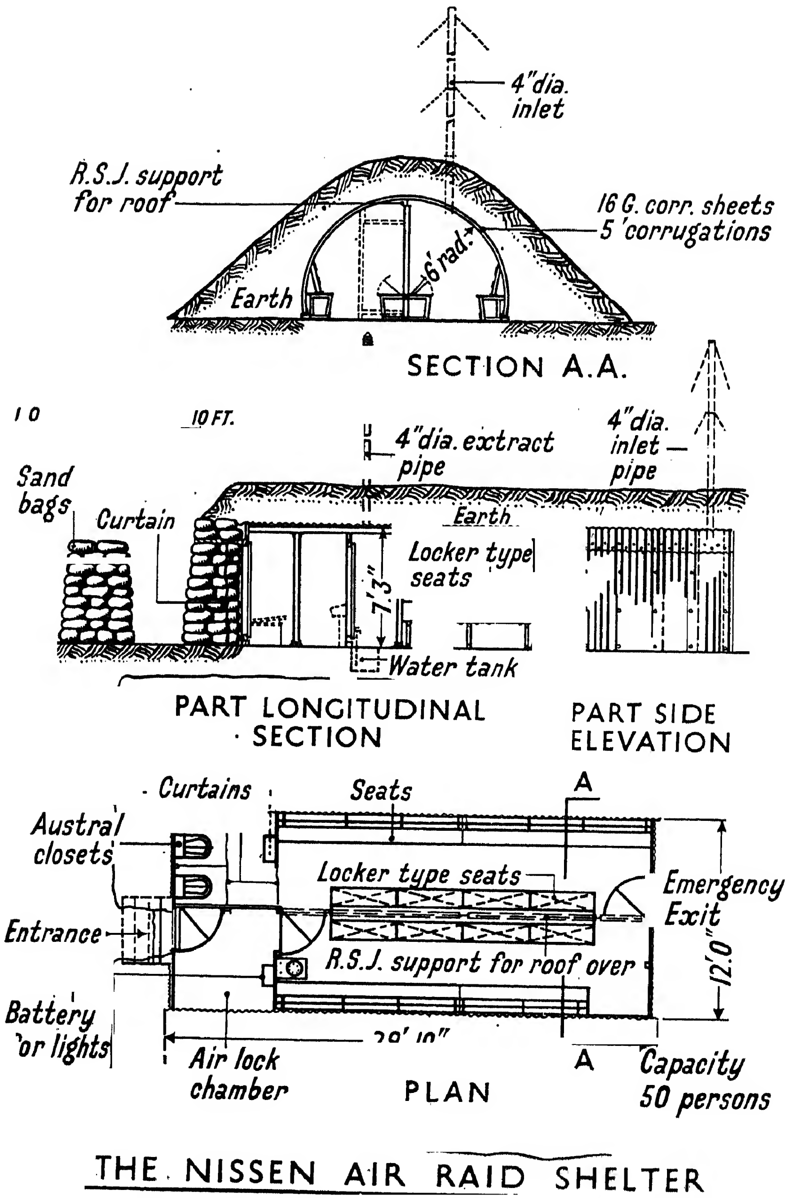


FIG. 201.—Arrangement of Nissen above-ground type of shelter for communal use. Capacity 50 adults.

"COMMUNAL" TYPE AIR RAID SHELTER TO ACCOMMODATE 50 PERSONS

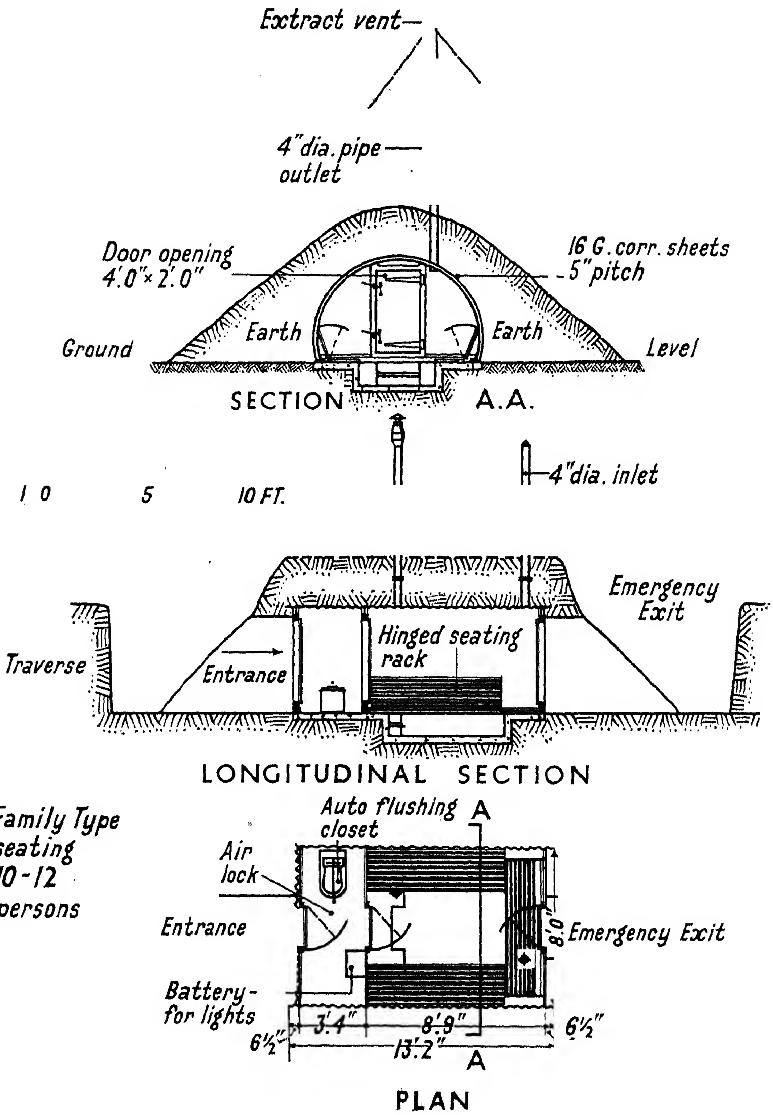
Specification

	£	s.	d.
Bearers. 3 × 3 × ½ in. angle cills, painted one coat and coach screwed to 2½ × 6 in. creosoted timber bearers	5	5	9
Roof Sheets. 16 gauge, 6/5 in. corrugated black sheets, holed to templates and curved to requisite radius, complete with necessary bolts and washers. All sheets painted one coat anti-corrosive paint on outside and one coat vigorised paint on inside . . .	39	7	0
Supporting Steelwork. Consisting of four stanchions and R.S. joist at roof level, painted one coat.	8	5	0
Bituproof. Sufficient material supplied to cover sheets externally after erection with two coats, reinforced with one layer of "Bituproof" membrane and for one heavy coat of finishing emulsion	12	4	0
Paint. Vigorised oil paint for application of two coats after erection	4	14	6
Curved Angle Frames for two ends and one cross partition . .	4	2	6
Ends. Two ends, in panels, of laminated tongued and grooved matching covered externally with ¼ in. flat asbestos and with galvanised corrugated steel sheets, cut to shape and supplied loose, except where doors occur. One door at each end consisting of laminated matching and asbestos covering protected with 16 gauge galvanised flat sheets on outside. Doors fixed to 3 × 4 in. timber framing by means of specially made cranked galvanised hinges and fitted with special handles. Rubber beading fixed into frame to ensure a perfectly sealed joint when doors are closed	19	15	0
Cross Partition. Including lavatory curtains. Partition generally as for ends, but with handles on door to operate from one side only	8	15	0
Longitudinal Partition. For lavatory	2	0	0
Seats and Lockers. Seats for 50 people. The centre seats with lockers and the side seats with backs but no lockers . .	13	3	0
Ventilating. Two 16 gauge steel welded 4-in. diameter pipes, complete with steel hinges and welded to roof sheets. Intake pipe fitted with cone cap and hand-operated fan drawing in air at the estimated rate of 6,000 cub. ft. per hour. Outlet pipe fitted with "Univac" extract ventilator. Stays comprising four wire guys per stack, complete with strainers and stakes. Exclusive of filter	22	8	3
Lighting. One 6-volt dry charged Exide battery connected with a 2-pin socket. Five 6-volt 6-watt double-pole S.B.C. bulbs, switch, panels and accessories	7	7	6
Sanitation. Two Austral portable automatic flushing closets, complete with sufficient solvent for the first charge. Trough and outlet	11	0	0
Tank and Pump. 25-gallon galvanised tank, 24 × 17 × 17 in., 14 gauge with 8-in. handhole and rubber ring, complete with delivery pump	2	12	6

The price for the above materials complete is £161 nett F.O.R. Works (subject to fluctuations in commodity prices).

A delivery charge for approximately 3½ tons of material should be added.

The approximate cost of erection, exclusive of builders' work and earth-covering, is £25.



THE NISSEN AIR RAID SHELTER

Fig. 202.—Arrangement of Nissen above-ground shelter for the use of two average families (capacity 10 adults or, say, 4 adults and 8 children).

"FAMILY" TYPE AIR RAID SHELTER TO ACCOMMODATE 10–12 PERSONS

Specification

	Price. £	s.	d.
Bearers. $3 \times 3 \times \frac{1}{4}$ in. angle cills, painted one coat and coach screwed to $2\frac{1}{2} \times 6$ in. creosoted timber bearers	2	8	6
Roof Sheets. 16 gauge, 6/5 in. corrugated black sheets, holed to templates and curved to requisite radius, with all necessary bolts and washers. All sheets painted one coat anti-corrosive paint on outside and one coat vigorised paint inside	11	13	0
Bituproof. Sufficient material to cover sheets externally after erection with two coats, reinforced with one layer of "Bituproof" membrane and one heavy coat of finishing emulsion . . .	5	0	0
Vigorised Paint. Sufficient material to cover inside with two coats vigorised paint after erection	2	5	0
Curved Angle Frames for ends and partitions	2	18	0
Ends. Two ends, in panels, of laminated tongued and grooved matching, covered externally with $\frac{1}{4}$ in. flat asbestos and with galvanised corrugated sheets, cut to shape and supplied loose. One door at each end consisting of laminated matching and asbestos covering with 16 gauge galvanised flat sheet iron on outside. Doors fixed to 3×4 in. timber framing by means of specially made cranked galvanized hinges and fitted with special handles. Handles on one door to operate from both sides and for emergency door from one side only. Rubber beading fixed into frame to ensure a perfectly sealed joint when doors are closed	14	0	0
Partition. Generally as for ends, but with door handles to operate from one side only and without galvanised corrugated sheets .	5	19	8
Seats for 10 to 12 persons with backrests. The backs may be placed across the building to provide sleeping accommodation .	2	5	6
Ventilation. Two 16 gauge steel welded 4-in. diameter pipes, complete with steel hinges and welded to roof sheets. Intake pipe fitted with cone cap. Outlet pipe fitted with "Univac" extract ventilator. Stays, comprising four wire guys per stack with strainers and stakes. Complete with fan but exclusive of filter	23	3	6
Lighting. One 6-volt dry charged Exide battery with fittings, including all switches, wiring and lamps	6	12	8
Sanitation. One Austral chemical closet with sufficient solvent for first charge	4	14	2

The price for the above-mentioned materials complete (subject to fluctuations in commodity prices) is £81 nett F.O.R. Works.

A delivery charge for approximately $1\frac{1}{2}$ tons of material should be added. The approximate cost of erection, exclusive of builders' work and earth-covering, is £13.

Shelters can be constructed to any required length by the addition of extra sections.

Similar shelters are, of course, available in all the approved trench lining systems described in Chapter IX.

Figs. 201, 202 and 204 show a type of Nissen air raid shelter which, it is claimed, will provide personal protection against all risks except a direct hit.

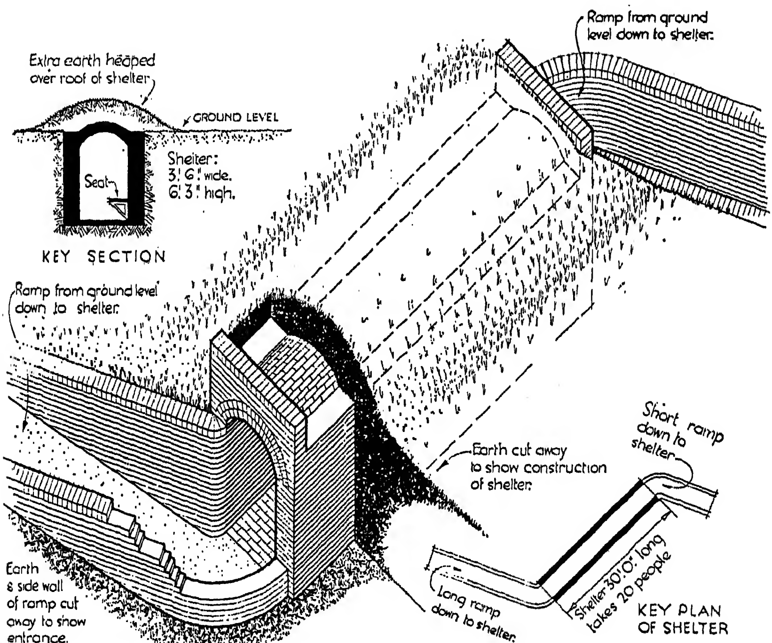
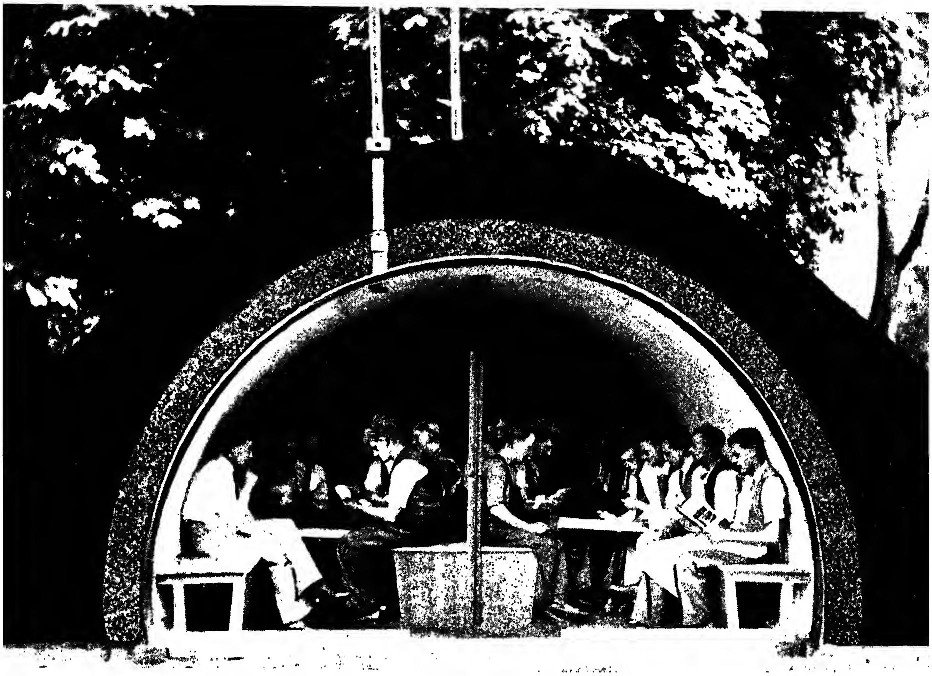


FIG. 203.—A brick-lined shelter of the covered-trench type.

Construction

The standard Nissen building is adapted by the provision of additional support along the middle as shown and a covering of concrete and earth added.

The main body is built up of curved sheets of corrugated steel 16 g. bolted together to form a section of a tunnel. The exterior is treated with " Bituproof " Anti-corrosive Solution to prevent corrosion of the steel plates. This solution is



-Sectional view of Nissen type of above-ground air raid shelter for communal use (see also Figs.

extremely resilient and effectively seals any possible source of air leakage.

Ends and partitions are made up in panels ready for fixing into the curved frames which are bolted to the sheets.

Gas-tight doors are fitted. These are faced with steel, backed by asbestos, wood and mounted on two thicknesses of timbering. The doors are so mounted that in the closed position they lend additional strength to the frames.

Gas-tightness is obtained by means of a rubber fillet, similar to windscreen wiper rubber, the flat part being let into a groove running around the door framing, the tubular part of the rubber remaining above the surface of the framework. When the door is closed by means of two pressure handles operating refrigerator door type cam locks, this tubular rubber is compressed, thus tightly sealing the door.

The doors are treated inside and out with Vigorised Paint which has been shown by tests to afford a definite resistance to the destructive action of mustard gas and to rigorous decontamination processes.

Ventilation

Two 4 in. steel pipes, rising 30 ft. above ground level, are let into the roof of the shelter, being bolted to short lengths of pipe welded into the roof sheets.

One of these is an exhaust pipe fitted at the top with a revolving extract ventilator; this is for the discharge of vitiated air. The other, the inlet pipe, is connected to a hand-driven fan delivering 75 cub. ft. of filtered air per minute. Each of these pipes consists of two lengths bolted together with flanged joints. These flanges are hinged together to allow the pipes, when not in use, to rest on top of the earth reinforcement ready for erecting when required. It is therefore unnecessary to keep the pipes permanently erected. In case of emergency it is a simple operation to make the joints and raise the completed pipe lengths by means of steel guys secured to ground stakes. Should the ventilating pipes be damaged they can be sealed by stoppers provided. Arrangements are made for a filtration unit, on the same principles as the container of a

respirator, to be incorporated in the air intake system, for the adsorption and/or filtering-out of poison gas.

Lighting

Lighting is supplied by a 6-volt lighting set supplied by the Chloride Electrical Storage Company Limited, or alternatively by a "Nife-Neverfayle" Set.

Three 6-watt lamps are fixed in the main chamber and 6-watt lamps in the air-lock and lavatory. A main switch is fixed at the entrance to the air-lock and another for controlling the light in the lavatory compartment.

It is desirable to have a duplicate battery in readiness to provide for the contingency of a prolonged raid period. At full load the battery will give eighteen hours' illumination.

Water Supply

In the case of the Communal (or "Fifty Person") type shelter a supply of water is obtainable from a 25-gallon galvanised tank fitted with a small hand pump.

The tank is supplied with a jointed coverhole for easy cleaning out purposes and, being sunk into the ground, it does not occupy valuable space and the water is kept cool. The water supply, on the basis of fifty occupants, therefore works out at 4 pints per person, which should prove ample.

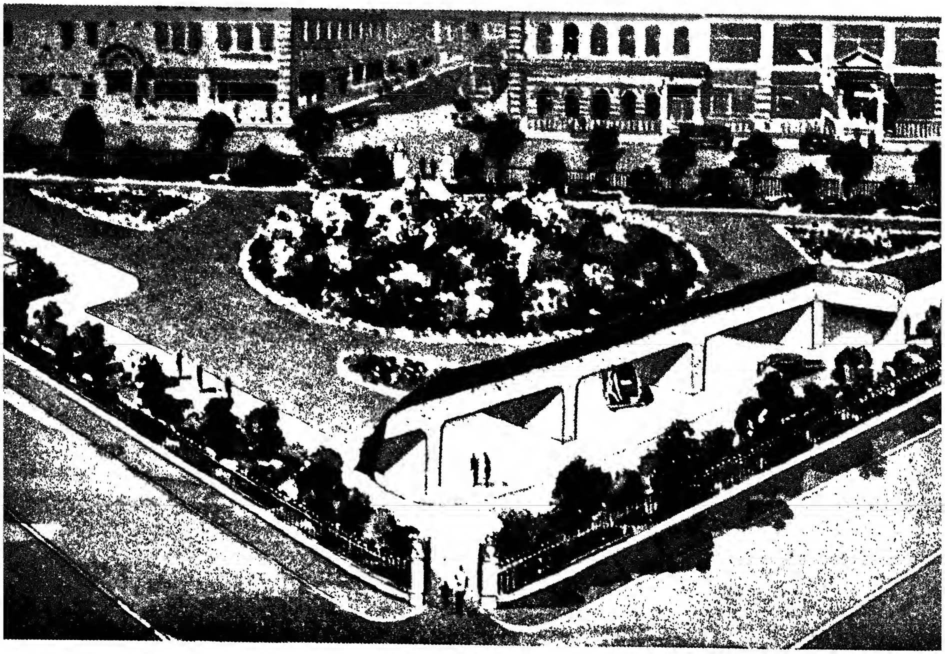
No tank is fitted in the case of the Family type shelter, where water for the use of the smaller number of occupants could easily be kept in suitable stoppered jars.

Sanitation

Two Austral automatic flushing closets are fitted in the lavatory compartment. A wide trough, to be used as a urinal, and in case of sickness, is also provided. The discharge pipe from this trough is led out to a small soakaway underground.

Seating

Wooden box-seats, with back rests, are provided and run the whole length of the main chamber—two and an end seat in the case of the Family type shelter and four in the Communal type, where the two central seats are arranged back to back. The seats have hinged lids, which enable the locker compart-



205.—Garage under public gardens providing the much needed peace-time accommodation for shelter for the floating population in an air raid.

desirable to adopt a *standard* degree of protection in such public shelters in order to prevent a be of the highest efficiency.

ments beneath to be used for storage purposes—food, clothing, personal effects and stores generally.

In the case of the Family type shelter the boarding forming the seats can be re-arranged to form sleeping boards.

TABLE XCIII

Type of Shelter.	Internal Surface Area.	Floor Space.	No. of Occupants per Home Office Scale.		No. of Occupants recommended.
	Sq. Ft.	Sq. Ft.	6 sq. ft.	3½ sq. ft.	
Family .	289	65	11	18	10 adults, or, say, 4 adults and 8 children. (Two average families.)
Communal .	870	268	45	77	50 adults.

Protection for the Floating Population

In spite of the provision of shelters at all centres of occupation and in the homes of the people, many will find themselves in the streets at the time of an air raid warning. For these the underground garage, which may ultimately be found in practically every square, would be a reasonably safe refuge. Fig. 205 shows a type of construction which could usefully be adopted. This is a form of cut-and-cover structure with approaching ramps which would be provided in an emergency with gas locks. The heavy concrete roof supported on thick dividing walls automatically separates the interior of the shelter into cells of a size suitable for the accommodation for fifty people. Ventilation, lighting, water service and sewage lift installation should be independently installed for each of the shelters and emergency exits provided for each.

For providing for the people in the streets of their locality civil authorities will doubtless take advantage of all suitable basements in public buildings; there will, however, inevitably be a considerable amount of new construction.

The refuges must be so distributed that they can absorb within ten minutes the floating population to be catered for, and in order to render the cost of the work reasonably economic they should preferably have a dual function so that they may serve some useful purpose in normal times. Public subways

and underground garages at once suggest themselves, and their more general use would minimise the congestion in the streets.

Fig. 206 shows a scheme for a combined Class 5 shelter and underground cycle park, as suggested in the Supplement to the *Architect and Building News*, March 3rd, 1939.

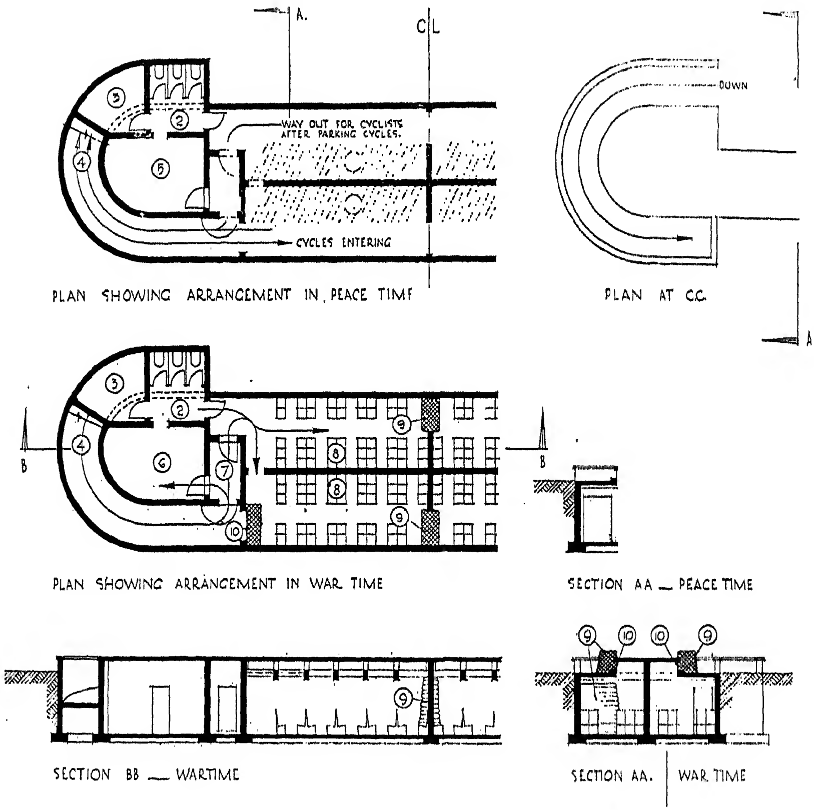


FIG. 206.—Underground cycle park-cum-shelter.

1. Represents parked cycles—twenty-four in each compartment.
2. Closets.
3. Ventilating and emergency lighting plant.
4. Ramp.
5. Storage for seating in peace-time.
6. First-aid room in war-time.
7. Gas lock.

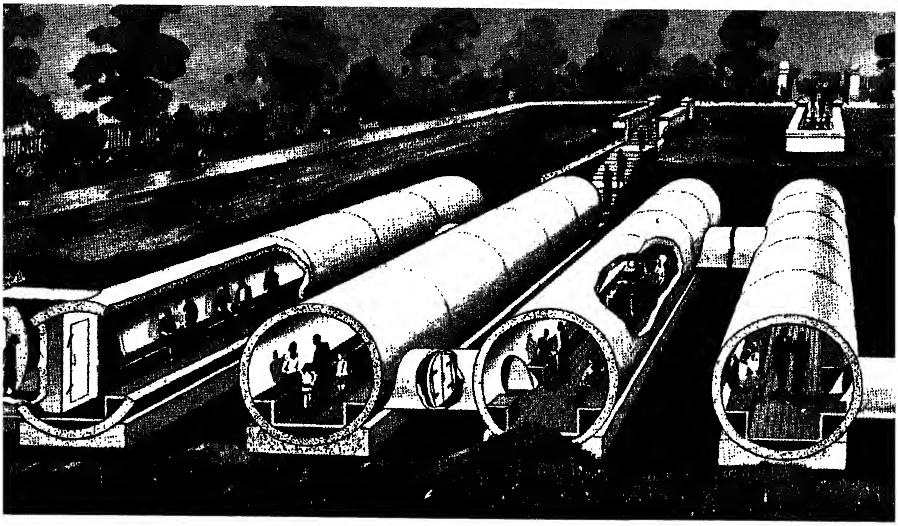


FIG. 207.—Cut-away view showing connected concrete tube shelters under open spaces.

FIG. 208.—Cut-away view showing concrete tube

8. Seating for forty-eight persons.
9. Sand-bags.
10. Steel shutter.

One of the most convenient and economical ways of constructing a public splinter-proof shelter is to use large diameter pre-cast concrete tubes, laid like a section of a sewer partly above ground and with a mound of earth over the top. If equipped with a ventilating and gas-filtration plant, a tube 72 or 78 in. diameter by about 50 ft. long would accommodate fifty persons. Pre-cast concrete tubes up to 90 in. diameter are obtainable.

Multiple concrete tube shelters could be installed under city squares without spoiling the amenities. Each unit would accommodate fifty persons, and would have its own entrance. The whole group could be interconnected and ventilated by a central gas-filtration plant. Gas-proof doors in the connecting tubes would prevent the immobilisation of the rest of the system if any of the units should sustain damage. The main tubes would naturally be spaced as far apart as space permits for the accommodation of the scheduled number of persons. (See Figs. 207 and 208.)

GERMAN DESIGNS FOR SPLINTER- AND GAS-PROOF CONCRETE TUBE SHELTERS

The following embodies translated extracts from a leaflet issued by a prominent German firm of concrete pipe manufacturers. The lay-out plans are interesting and practical, and photographs indicate that concrete tube shelters have been installed in Germany in an efficient manner. Fig. 209 shows a number of arrangements.

The following are some of the chief points mentioned in the German leaflet :—

These shelters represent a complete development in the structure of air raid shelters by reason of practical utilisation of space, use of the minimum quantity of material and economical arrangement.

Their practical shape ensures a high degree of safety. The standard tube units are 2·5 m. (= 8 ft. 2 in.) long by 2,000 mm. (= 79 in.) internal diameter. The shelters can be assembled to suit any desired plan, and installed on the surface with a

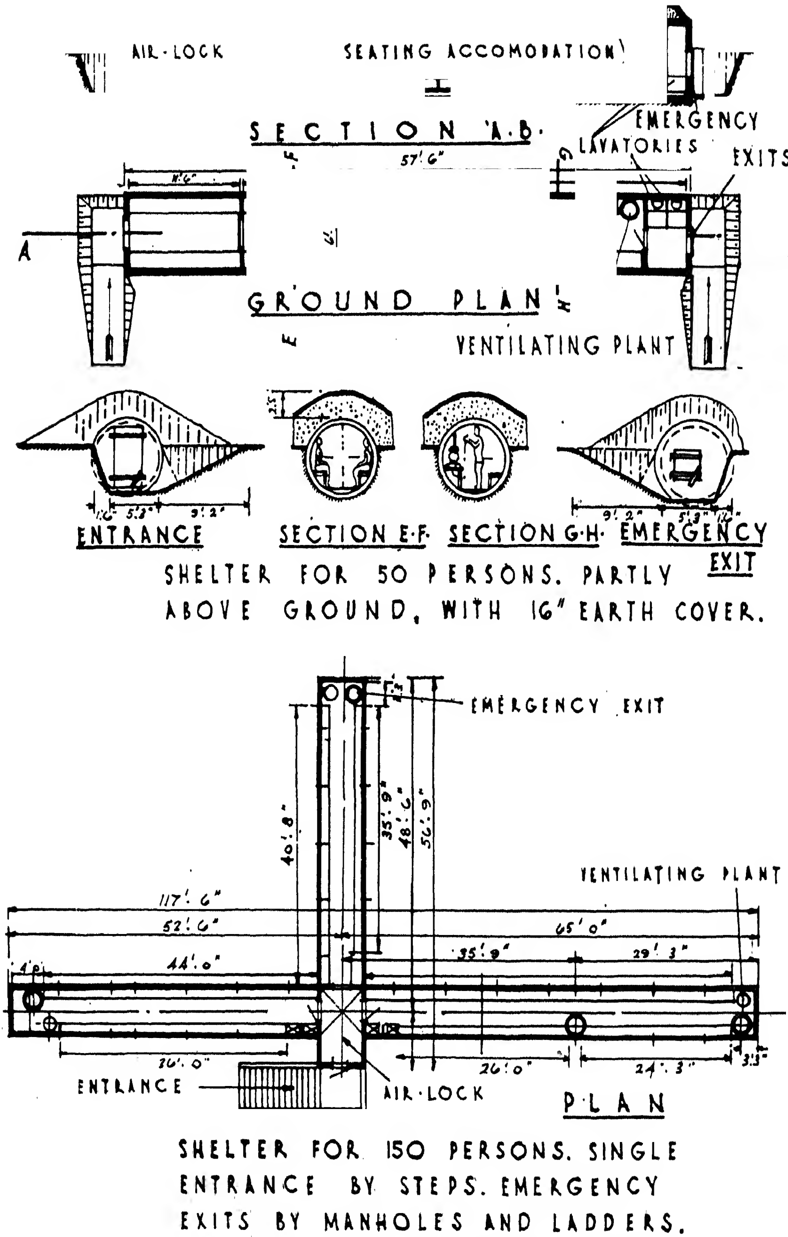


FIG. 209.—German designs for concrete tubular shelters.

splinter-proof earth covering, or below ground level, even in water-bearing strata, or as gallery structures. Absolute tightness at the joints is obtained by means of a bitumen compound in the grooves and rebates.

The shelters can be designed for the accommodation of any number of persons and laid out to the best advantage in the space available. Steel fittings and lugs are cast into the concrete tubes and connected to the reinforcement. The lugs, etc., serve for bolting together and for the fixing of bulkheads. The seats can be arranged to tilt up, thus increasing the scope for using the shelters as stores in normal times.

The advantages are rapid construction of standard parts for complete shelters, easy transport, simple and quick installation and high degree of protection. This means a great saving, and represents a sound technical solution to the problem of constructing air raid shelters.

It should be noted that the capacities shown in the German lay-out plans assume that ventilation and gas-filtration equipment is installed in each shelter. Without ventilation the capacities would be less.

In Berlin alone it is said that more than 70,000 air raid shelters have been prepared, while Paris has made provision for the protection of 2½ million of her three million population.

In Paris, however, seven stations on the Metro. have been selected for use as public air-raid shelters in case of need. One of the main features of the special work involved to render the Metropolitain of Paris suitable for this purpose is the fitting of swing gas-tight doors in series of seven in each of the various passages leading to that portion of the station constituting the air-raid refuge. Doors are normally kept open during the normal use of the railway.

Very large capacity air-filtration plant in compartments inside the protected area is installed and one of the filters used on the installation is illustrated in Fig. 36. The capacity of these public shelters in the Metro. system varies from a few thousands up to several thousand persons, and the cost of the work has been stated to be about £2 per head. Owing to their considerable depth below ground practically the whole of the cost is for the gas-proofing and air-filtration work, and the protection afforded is practically 100 per cent.

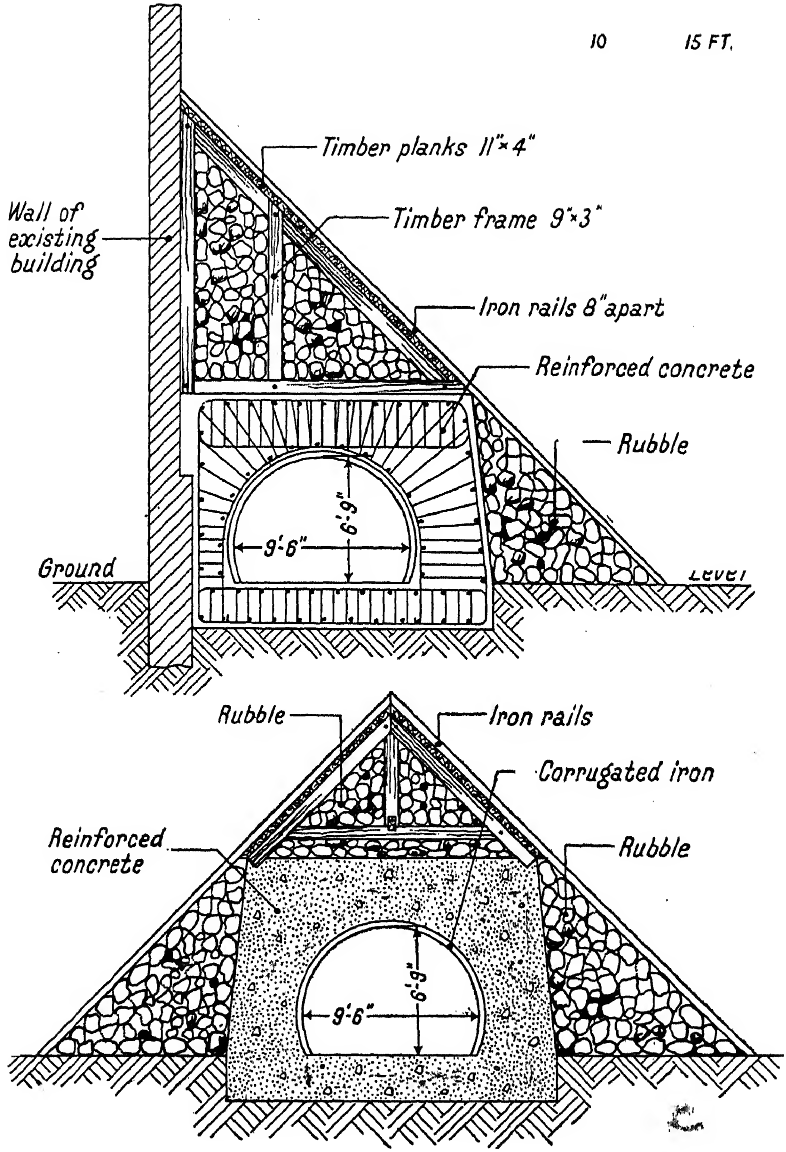


FIG. 210.—Types of above ground bomb-proof shelters as recommended by the French Government for protection against direct hits of medium weight high explosive bombs.

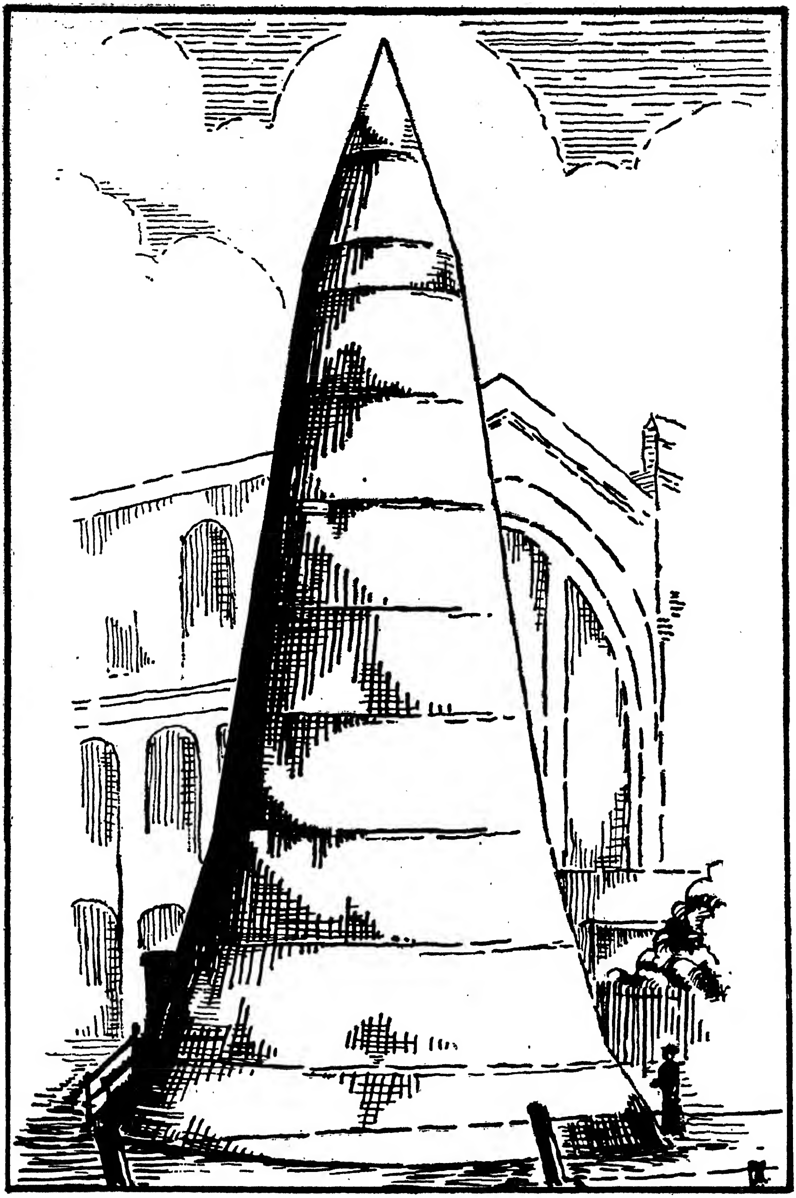


FIG. 211.—German "ant-hill" type of public bomb-proof shelter in reinforced concrete 80 ft. high, to accommodate 300. It is circular on plan and its steeply sloping sides minimise danger of undeflected impact.

In London the tubes are very deep, but owing to the grave danger of flooding in the event of bursting of sewers or water mains during an air raid and also owing to the difficulty of rendering them reasonably gas proof and ensuring adequate ventilation in the failure of the main electricity supplies, they are not being considered as available for public air-raid shelters.

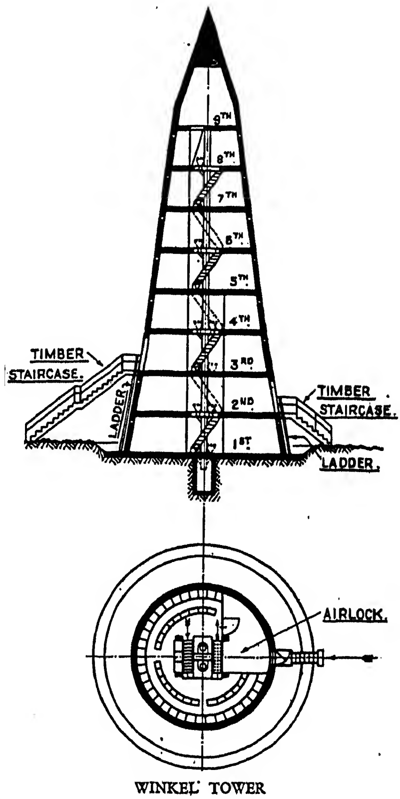


FIG. 212.—Sectional view of the Winkel tower.

Many schemes for public shelters have been proposed, and the authorities are being inundated with suggestions of all kinds, some quite practical and others quite unsuitable owing to their prohibitive cost.

A discussion of the pros. and cons. of proposals of this kind is not within the scope of this volume, but it is evident that

the very careful consideration which is being given to these proposals will result only in the adoption of those really most suitable.

Owing to the vital necessity of insisting upon the adoption of the principle of dispersion the large public shelter is not likely to be adopted to any considerable extent in this country.

Outside Shelters

Outside shelters above ground giving protection from direct hits of medium weight bombs may be constructed generally as shown in Fig. 210, as recommended by the French Government, or as shown in Fig. 211 as installed in Berlin.

In each case the principle of deflection of the bomb is utilised.

The "Ant-hill" type illustrated is a conical tower in reinforced concrete, 80 ft. high, and it can accommodate 300 people.

It is a type which is only likely to be adopted for temporary shelter for the floating population.

The walls are 4 to 5 ft. thick in reinforced concrete, and there are a number of interior floors connected together with a spiral staircase.

Ventilation is from the top and there is no filter.

A sectional view is given in Fig. 212.

Wardens' Shelters

Outside wardens' shelters constructed to Class 6 protection ought to be designed to function ultimately as public rest rooms, bus passenger shelters, refreshment rooms, etc., in times of peace, avoiding as far as possible unproductive expenditure upon purely wartime structures.

CHAPTER XI

BOMB-PROOF SHELTERS

Roofs

For the housing of vital units in the essential services and for the protection of national treasures bomb-proof shelters may be required.

These may be established at ground level, just below the ground or at great depths below the surface.

Fig. 213 shows a Swiss type of bomb-proof shelter and a suitable internal arrangement. The type of reinforcement is also indicated on the section.

Generally speaking, there is no advantage in covering a bomb-proof shelter with a few feet of loose earth when direct hits are to be resisted as the nose wave in front of the approaching bomb almost invariably clears off the upper layers of covering *before* the bomb strikes.

This effect is more noticeable with high velocity armour-piercing shells.

In using the figures of the required thicknesses for protection given in Table XII, this fact must be borne in mind.

It is only at the greater depths of submergence that the benefit of the earth covering is at all appreciable.

Fig. 214 includes a graph from which the curtailment of the thickness of the roofs of bomb-proof shelters at various depths below ground level can be obtained.

For example, a shelter proof against the 1-ton H.E. bomb should have a reinforced concrete roof at least 6 ft. 7 in. thick if constructed at ground level, with no further protective covering and a roof of 2 ft. of reinforced concrete if constructed 66 ft. below the surface of the ground.

Intermediate values, such as 5 ft. thickness of reinforced concrete 42 ft. below the ground can be read off from the graph.

Scales of feet thicknesses for roofs of shelters and covers

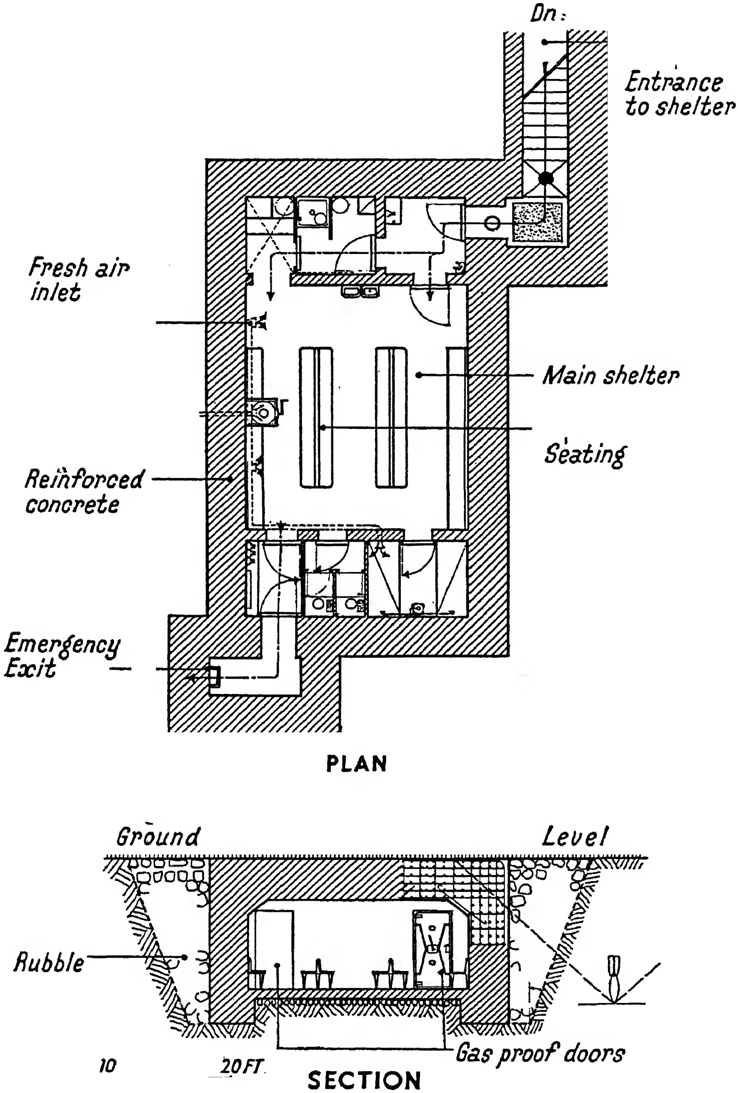


FIG. 213.—Swiss type of bomb-proof shelter, showing arrangement of air-locked entrance, decontamination room, toilets, gas mask and tool stores, food store and emergency exit.

Roof 3′ 7″. Wall 3′ 4″ for 220 lb. bomb.
" 4′ 7″. " 5′ 0″ " 660 " "

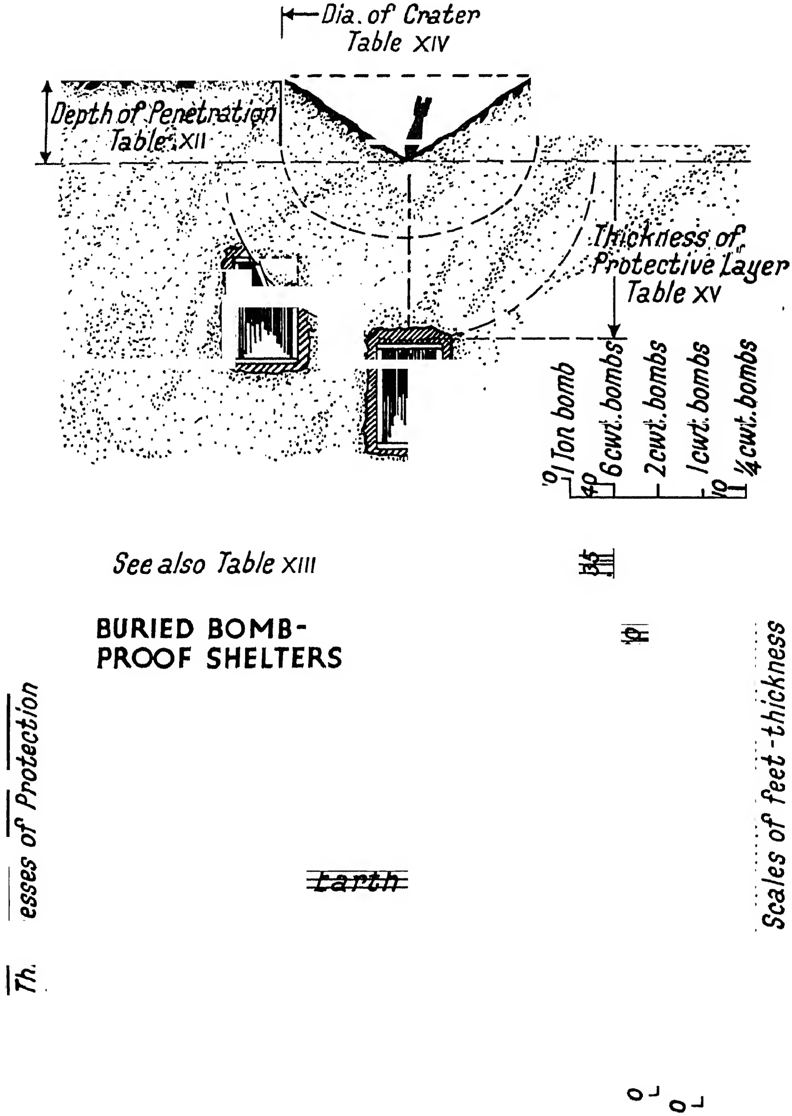


FIG. 214.—*Above.* Depicts the values tabulated in the recommendations.

Below. Includes a graph from which the curtailment of the thickness of the roofs of bomb-proof shelters at various depths below ground level can be obtained.

over, to provide protection from direct hits of bombs of 6 cwt., 2 cwt., 1 cwt., and $\frac{1}{4}$ cwt. gross weights respectively, are plotted in such a position to permit the utilisation of the same graph.

The dimension from the zero on the appropriate scale to the curved graph gives the thickness of reinforced concrete roof required and the intercept between the two graphs the required thickness of the earth covering.

For example, protection against 2 cwt. bombs can be secured with $3\frac{1}{2}$ ft. thickness of reinforced concrete buried 11 ft., or 3 ft. thickness, 17 ft. down. Protection against 6 cwt. bombs would require 3 ft. thickness of reinforced concrete 27 ft. below the surface.

On the upper part of same figure is a diagram illustrating the values given in Tables XIII, XIV and XV respectively.

The roof thicknesses given in the tables and shown in the graph are all based upon the special type of reinforcement shown at A, in Fig. 69, and are determined principally upon the resistance to punching shear.

Additional beam reinforcement or even additional thickness in roofs may be required when spans exceeding 20 ft. are involved, but in this case vaulted ceilings are preferable as providing arched strength additional to the ordinary beam effect.

Large bomb-proof shelters in the open are best left uncovered altogether unless they can be buried more than 50 per cent. of the depth required to give total protection and provided the roof is of the requisite thickness.

A convenient summary of proof thicknesses to perforation and explosion of high explosive bombs compiled from foreign sources is given in the table on p. 426.

No shelter can be regarded as bomb-proof unless it affords complete protection against a bomb of specified weight with delayed fuse; thus a shelter made to be proof against a $\frac{1}{2}$ ton bomb would not necessarily be proof against a 1 ton bomb, and it is therefore a merit in design if the shelter lends itself to strengthening as may be necessary to provide for increased protection.

The use of a burster course on a shock-absorbing layer over the top of the shelter may be a source of real danger unless the burster course itself is sufficiently strong completely to resist

Table XCIV

Proof Thicknesses to Perforation and Explosion of H.E. Bombs compiled from Foreign Sources

Bomb Ref.	Weight of Bomb.	Calibre of Bomb.	Sectional Density of Bomb.	Weight of Filling of Bomb.	Proof Thickness Penetration and Explosion.					
					Sandy Soil.	Firm Gravel.	Soft Rock.	Mass Concrete.	Reinforced Concrete.	Specially Reinforced Concrete.
1	2	3	4	5	6	7	8	9	10	11
	lb.	in.	lb./in.^{2}	lb.				$u = 2{,}200$ lb./in.^{2}	$u = 2{,}800$ lb./in.^{2}	$u = 5{,}700$ lb./in.^{2}
A	110	7·1	2·78	57	21′ 6″	18′ 0″	11′ 6″	4′ 7″	2′ 10″	2′ 4″
B	220	9·8	2·92	120	29′ 6″	24′ 8″	16′ 6″	7′ 0″	3′ 6″	3′ 8″
C	660	14·2	4·20	360	43′ 0″	36′ 0″	24′ 8″	9′ 3″	4′ 11″	4′ 7″
D	2,200	21·6	6·00	1,200	65′ 8″	—	—	9′ 10″	7′ 9″	6′ 7″
E	4,000	25·6	7·80	2,200	—	—	—	—	9′ 4″	—

NOTE. u = minimum crushing strength of the concrete in lb. per square inch after 28 days.

the penetration and explosion of the bomb for which it is designed. The upper layer must also be made to extend round the shelter sufficiently to prevent a bomb reaching the shelter by oblique attack.

The French about 1890 embodied shock-absorbing layers of sand under detonating slabs of reinforced concrete in the design of shelters. The bed of sand, however, proved ineffective, for at the moment of explosion too great a pressure was produced in all directions in the sand, similar in effect to hydraulic pressure, and the construction cracked. Subsequently the French built fortifications entirely in reinforced concrete.

Dry sand is a good load-bearing material provided it has lateral support, and is thus prevented from escaping. If, however, the lateral support is provided the sand is completely enclosed and the effect above referred to is produced, thus nullifying any shock-absorbing properties. For this reason an intervening layer of light aerated concrete or weak pumice or foamed slag concrete (say 10–1 mix) is preferable, as it will contain air cells which will crush under impact, thus localising the effect without producing excessive pressures.

The French favour solid reinforced concrete shelters with provision of steel lining or close mesh reinforcement on the inside to prevent scabbing of the concrete. The Swiss also adopt a similar practice, but provide rubble filling round the outside of the shelter proper in order to provide interstices for the relief of the expanding gases from the explosion of a bomb, whilst the Italian practice is to utilise air space between the shelter and the outer protecting cover.

There is no doubt that if a separate shield is adopted it must be designed to take the full force of impact, penetration and explosion without perforation. It should be extended laterally to protect the shelter from oblique attack, and that the shelter proper should be designed to resist scabbing or spalling of the inner surface of the concrete by the provision of an air space between the shield and the shelter or by the use of steel linings or close mesh reinforcement.

To prevent the transmission of concussion or earth tremor to the occupants of the shelter it is desirable that the floor be constructed on a thick layer of sand or foamed slag inserted between the floor surface and the base of the shelter itself.

Bison Bomb Deflectors

These consist of a pyramid of concrete balls, each 15 in. diameter, weight 112 lb., and cost 4*s*. each. 18 in. diameter deflectors cost 7*s*. each.

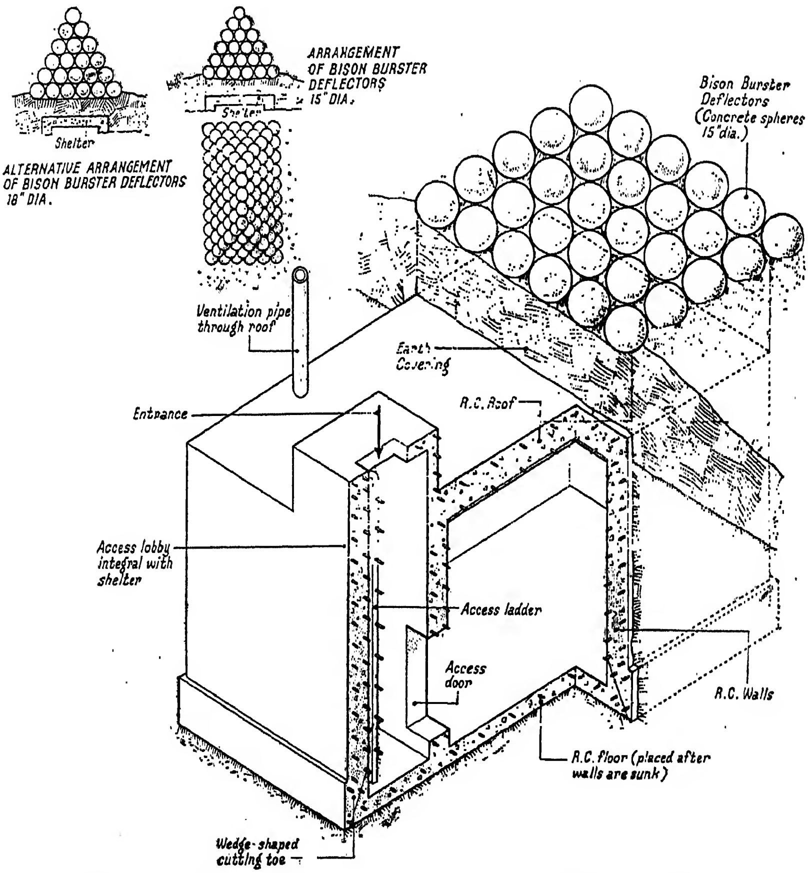


FIG. 215.—Cut-away view of shelter showing arrangement of Bison bomb deflectors.

Messrs. Concrete Ltd. have carried out elaborate tests of the device, and have shown that the Bison bomb deflectors give a greater degree of protection than the same mass of concrete in the form of a single slab.

The theory is that, at whatever angle the bomb may hit the burster course, it will encounter the rounded surface of a

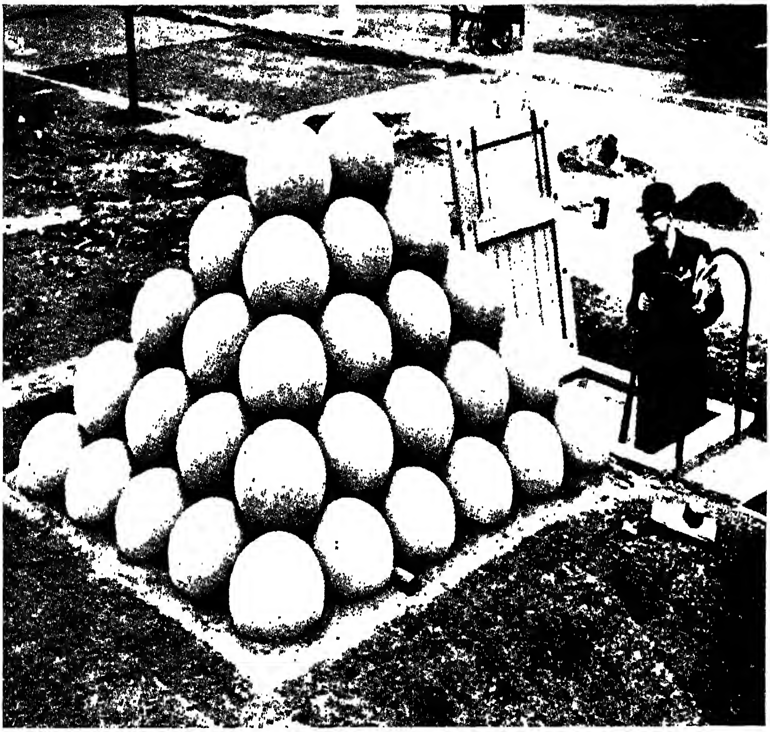


FIG. 216.—External view of shelter showing pyramid of Bison bomb deflectors arranged on the roof.

[To face page 428.

FIG. 217.—Showing the result of an impact test on a shelter roofed in wood and completely protected by sandbags and a pyramid of Bison bomb deflectors.

material hard enough to change its direction, dissipate most of its energy in scattering the balls, and expend the rest in skidding along the surface of the ground, thus achieving the unconfined burst, which is always preferable to a tamped explosion. The arrangement is shown in Figs. 215 & 216.

Fig. 217 shows the results of a test using a dummy bomb weighing 1,204 lb. released from a height of 110 ft. and striking with a velocity of approximately 84 ft. per second and an energy of about 132,000 ft. lb.

Twenty 15 in. and twenty 18 in. deflectors in two layers successfully prevented any damage to a trench covered only with a wooden roof and three layers of sandbags.

Whether the bomb deflectors would really act in the same way when subject to bomb impact at the usual striking velocities—which are at least ten times greater than those used in the tests—has yet to be demonstrated; and whether the telekinesis effect of a bursting bomb would not be more pronounced when these "ready made projectiles" are available has also to be ascertained.

The test results are, however, very encouraging and prove that a closely packed heap of hard round balls has considerable deflecting power when subject to direct impact, and that smooth hard spherical units are preferable to loose random shape masses so often advocated for burster courses in the form of rubble.

PROPORTIONS FOR ROOFS OF BOMB PROOF SHELTERS

Table XCV shows sizes for protector slabs on shock-absorbing layers of sand or ballast, and Fig. 218 is diagrammatic of the arrangement envisaged. The thickness recommended for the protector slab "T" in feet is based upon concrete having a crushing strength of 2,800 lb. per sq. in. at twenty-eight days and shows a small margin of safety on the proof thicknesses given in Table XCIV.

The thickness of the shock distributing layer is recommended by the author to be double the thickness of the protector slab, but in the design of the roof of the shelter proper it is necessary to take into account the dead load of the sand and the protector slab as well as the dynamic load due to the impact of the bomb and partial penetration into the protector slab.

On the basis of calculation given on p. 42 the dynamic load has been calculated and the equivalent static load is taken as at least twice the average dynamic load. The diagram given in Fig. 218 shows the assumed cone of distribution of the load on to the roof of the shelter below, and from this the equivalent static load per square foot on the shelter roof has been worked out.

The necessity of full scale tests to ascertain the true action of a "sandwiched" layer of supposedly shock-absorbing

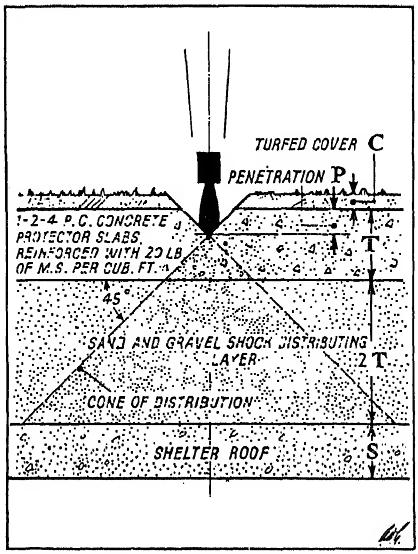


FIG. 218.—Diagram showing dimensions given in Table XCV.

properties is here very apparent. Compact sand is likely to act as a fluid and thus distribute the shock evenly over the roof, but a really resilient layer such as aerated concrete might well minimise the total load by compression, but concentrate it upon a smaller area, as shown by the cone of distribution.

Loads tabulated in the penultimate column of Table XCV include the dead load of the shock distributing layer, protecting slab and the turfed cover. On the basis of the utilisation of a high percentage of reinforcement top and bottom in the roof slab and stressing this reinforcement to 27,000 lb. per sq. in., the necessary thicknesses of the shelter

roof are tabulated in the last column; this is based upon a span of 20 ft., which is the maximum the author would recommend.

It will be seen on consideration of the diagram that the use of a shock distributing layer can hardly ever be economic, since the thickness of shelter roof required to resist the bending moment and shear stresses brought about by the dynamic load and dead load of material above makes this—at any rate in the case of the smaller bomb—just as thick as the protector

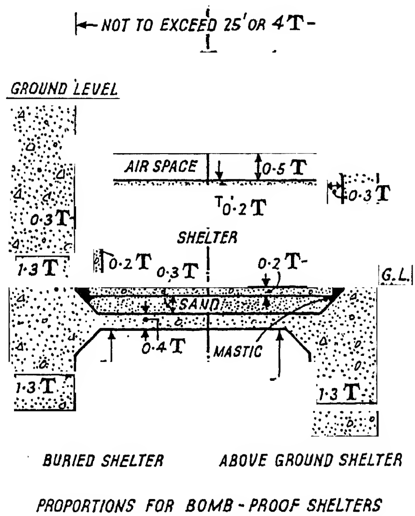


FIG. 219.—Diagram giving proportions of surface and above ground bomb-proof shelters.

slab itself. It is obvious, of course, if the thickness of the shock distributing layer can be increased, then the distribution which it is likely to effect will be greater and the equivalent total static load on the shelter roof will be reduced. On the other hand, the dead load is increased and the shelter itself is a considerable distance below the protecting slab.

Fig. 219 shows, on the other hand, the dimensions of above ground and below ground bomb-proof shelters in which the shock distributing layer of sand has been omitted. Table XCVI gives the data upon which the proportions have been worked out.

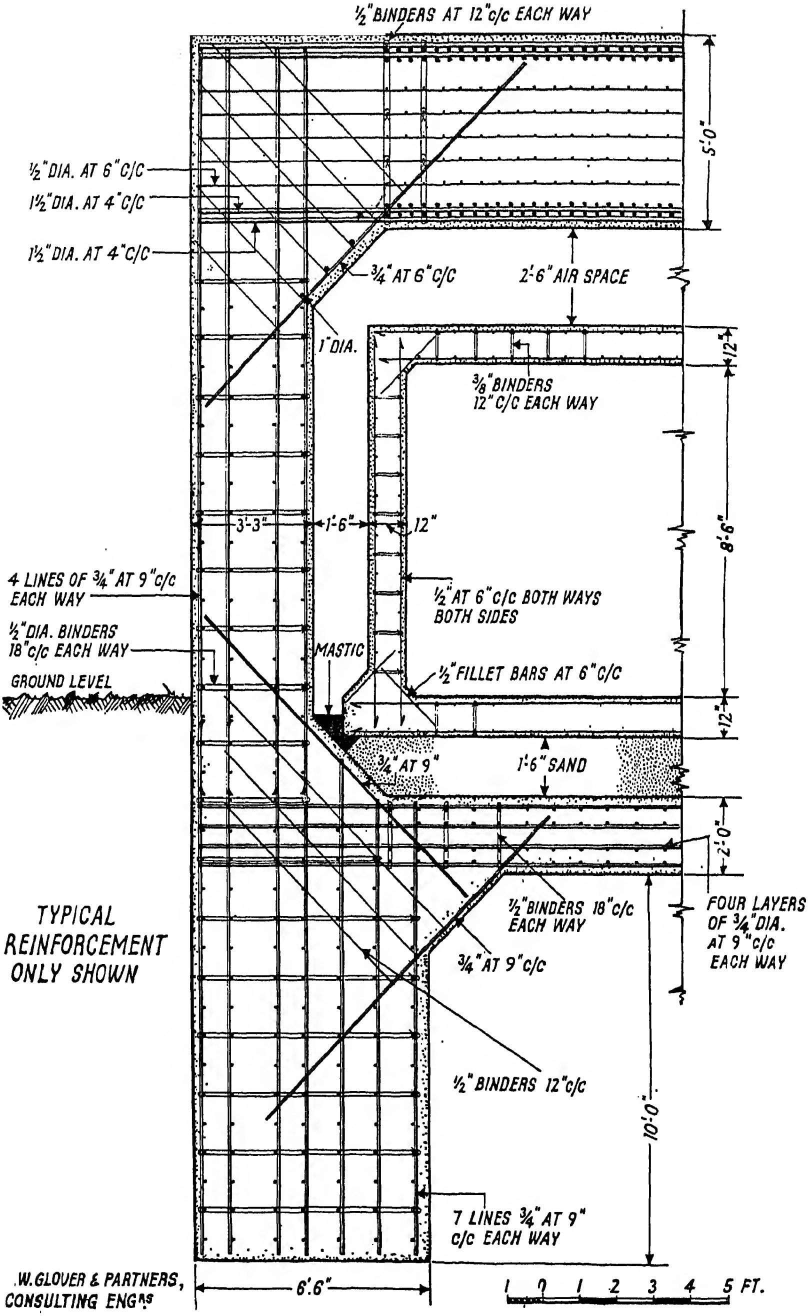


FIG. 220.—Detailed design of bomb and shock-proof shelter.

TABLE XCV

SHOWING SIZES FOR PROTECTOR SLABS ON A SHOCK-ABSORBING LAYER

Ref.	Bomb Weight. in lb.	Penetration "P" in Inches.	Turfed Cover "C." Thickness in Feet.	Thickness of Protector Slab "T" in Feet.	Thickness of Shock Distributing Layer in Feet.	Equivalent Total Static Load on Shelter Roof in lb. per sq. ft.	Thickness of Shelter Roof "S" for 20′ Span.
A	110	14	1	3	6	11,000	36″
B	220	15	1	3½	7	14,500	42″
C	660	22	1	5	10	15,000	45″
D	2,200	31	1	8	16	15,250	48″
E	4,000	40	1	10	20	15,500	60″

Based upon concrete having a crushing strength of 2,800 lb. per sq. in. at 28 days.

Table XCVI

Showing Dimensions for Roofs of Above Ground Bomb-proof Shelters

Ref.	Bomb Weight in lb.	Penetration "P" in Inches.	Proof Thickness of Roof in Feet.	Dynamic Load for Striking Velocity of 800 ft. per sec. lb.	Thickness for Protecting Roof for Span of 20 ft. each Way.	Min. Area of Steel Top and Bottom of Roof Slab in sq. in. per Foot Width.	Air Space "A" in Feet.	Thickness of Shelter Roof "S."
A	110	14	3	945,000	3′ 6″	4·0	1¾	8½″
B	220	15	3½	1,750,000	4′ 0″	7·0	2	10″
C	660	22	5	3,580,000	5′ 6″	10·0	2¾	13″
D	2,200	31	8	8,550,000	8′ 6″	14·0	4¼	20″
E	4,000	40	10	12,000,000	10′ 6″	16·0	5¼	25″

Based upon concrete having a crushing strength of 2,800 lb. per sq. in. at 28 days.

It will be seen that the thickness of the protecting roof for a span of 20 ft. in each direction is only 6 in. more than the proof thickness of slab required. The dynamic loads have been calculated for striking velocities of 800 ft. per second, and assuming that one bomb strikes the roof slab normal to the surface and in the middle of the span the area of steel required each way, both top and bottom of the slab, of the thicknesses tabulated is shown in column No. 7. The air space recommended by the author is shown in column No. 8, and the thickness of the shelter roof in column No. 9.

By the arrangement proposed the protecting roof of the

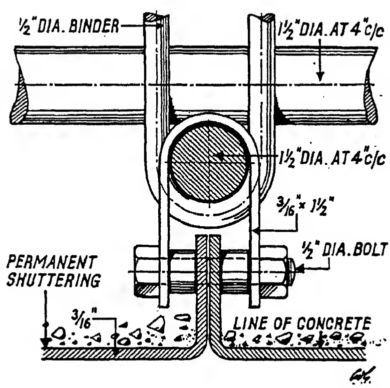


FIG. 221.—Showing details of permanent steel soffit shuttering attached to reinforcement.

structure is designed to deal with the dynamic load, both for bending and punching shear, and there is no such load on the shelter roof proper, the air cushion being sufficient to prevent transmission of heavy loads to the shelter roof. A detailed design for shelters based upon these principles is given in Fig. 220.

When a bomb-proof shelter is designed without a separate protector slab the roof itself should have a permanent steel soffit or be reinforced with close mesh reinforcement on the ceiling to deal with any possible scabbing of the concrete. In the case, however, of the second type, in which an air space is used between the protector slab and the internal shelter, the steel soffit should be on the underside of the protector slab.

It is, however, an advantage always to have a close mesh reinforcement on the inner surface of any shelter which might be subject to direct impact of projectiles or splinters.

A thin "bursting" slab over earth filling is a danger when hit by heavy H.E. bombs as the telekinesis effect is increased by the flying fragments of the slab broken up by the impact as well as the tamping effect upon the explosion.

"Bursting" courses or detonating slabs over earth covering are of most use in touching off the smaller bomb.

Lateral Protection

Swiss Government recommendations advise that the depth of the side wall foundations should be at least ½ metre deeper than the depth of penetration given in Table XV.

In the French Government recommendations external walls are required to be 25 per cent. thicker than the roof covering and they must never be less than 2 ft. 4 in. thick; furthermore, they must be made monolithic with the roof and reinforced in exactly the same way as the roof. A detonating slab level with the ground surface all round the shelter has advantages which will be apparent on consideration of the following:

The foundations must be arranged in such a way as to provide a protection against the effects of a projectile penetrating the ground in the vicinity of the shelter and exploding near the foundation. For this purpose arrangements as indicated on Fig. 222 may be adopted; in alternative A the depth of the foundations are arrived at by making dimensions a, b and c to aggregate the depth of penetration given in Table XII. The example shown on the above-mentioned figure is of a small shelter 10 ft. × 10 ft. × 10 ft. internal dimensions. The outlines given are for bombs weighing ¼ cwt., 1 cwt., 2 cwts., 6 cwts. and 1 ton respectively. In the latter case it will be seen that the walls are carried down a very considerable depth in order to provide protection to the interior of the shelter against a burst of a 1 ton bomb in the earth adjacent to the side walls.

In alternative B lateral protection is improved by the use of detonating slabs of a thickness equal to half that of the shelter roof and carried out all round the shelter to the amount shown on the figure. In this case the dimensions d, e, f and g

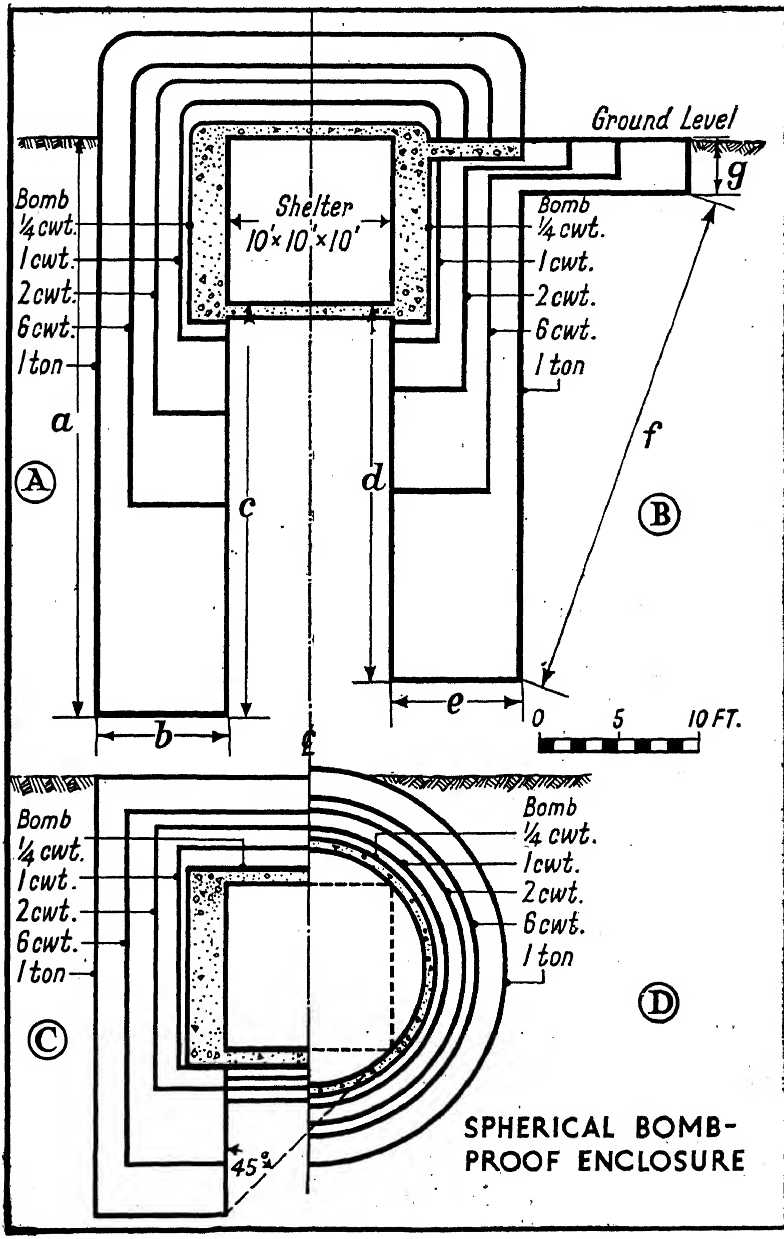


FIG. 222.—Outlines of heavy bomb-proof shelters. A and B, according to the French Government recommendations. C and D, author's proposals (see text, p. 438).

should aggregate the total depth of penetration given in Table XII. This shows some economy in the depth of foundations but unless the detonating slab is carried out to an extent very considerably more than the maximum internal dimensions of the shelter the economy possible in the depth of the side walls is not very material.

Both alternatives A and B are calculated on the basis of having a concrete floor of negligible resistance, say about 1 ft. of concrete.

In alternative C however this same bomb-proof shelter is drawn with a foundation raft, having a thickness equal to half that of the roof. The depths of the side walls are worked out exactly as in the case of alternative A except that there appears to be no necessity to carry them down deeper than the internal width of the shelter. In this alternative it must be remembered that although the shelter is unlikely to be penetrated the whole structure may be moved by the force of the explosion and the concussion received by occupants would in all probability prove fatal, were a burst to occur close to the shelter or a direct hit be obtained. The use of such construction in the open is principally to house automatic control gear used in defence operations or in the essential services.

Alternative D shows further economies which can be effected in both excavation and material. The form recommended in this case is that of a complete sphere of reinforced concrete generally to the thicknesses shown on the drawing. The construction has the added advantage of minimising the possibilities of a direct hit in a completely radial direction. The impact of the bomb is more likely to be somewhat tangential and the deflection thus caused would largely minimise the shock of impact. Access to and egress from such shelters would necessarily be very carefully protected and kept as remote as possible from each other. The principles of construction of such connections have already been discussed, but there is no doubt that where possible bomb-proof shelters should be constructed at low levels in order to minimise the danger of the effects of excessive concussion and also to economise in the material of constructions.

All large shelters should be divided into small sections accommodating no more than fifty persons and the dividing

walls should be stronger than the roof or external walls in order to localise the effects of direct hits on any particular section. On the other hand, if they are partition walls no thicker than quarter of the thickness of the roof they should not be bonded to the roof but the top course should preferably be laid in cork or similar resilient material to permit of the elastic deflection of the roof without causing the dividing partitions to be fractured.

Walls of Shelters above Ground

When the shelter is constructed above ground level the dynamic load on the wall due to direct impact is less than that on the roof, since the angle of incidence of the bomb on the surface is such that its normal component is between a half and a third of that on a horizontal surface. Further, the bomb is to a large extent deflected down the side of the shelter, expending the major portion of its energy in penetrating the earth surrounding the shelter. For this reason the side walls of shelters need not normally be more than two-thirds of the proof thickness required for the roof.

The angle of impact, *i.e.*, the angle between the direction of the projectile and the surface of the target, determines whether the projectile will penetrate, detonate or ricochet. The limiting angles for ricochet have been found [157] to be as follows :—

For small spherical projectiles with velocities of about 2,000 ft. per second the limiting angle for ricochet on water is	7	degrees.
For shells striking smooth sea . .	25	,,
For 4 in. dia. shells striking sand. .	10	,,
For 12-in. dia. shells striking sand. .	28	,,

Petry gives for bullets a limiting angle of 15 degrees for earth and as much as 30 degrese for masonry and brickwork.

Considering, therefore, the limiting trajectories for bombs given in Fig. 6, it will be seen that, generally speaking, a bomb striking a vertical surface will ricochet from it, provided there is sufficient strength in the structure as a whole to resist the shock of oblique impact.

Walls of Shelters below Ground

With buried shelters, however, the side walls may have to withstand the full force of the tamped explosion due to a bomb bursting in the ground immediately adjoining the shelter, and for this reason the thickness of 1·3 times that of the roof thickness is recommended by the author.

The general proportions for the various sections of bomb-proof shelters are indicated in Fig. 219, the left-hand side showing the shelter buried to ground level and the right-hand side the shelter constructed above ground level. The thickness required for the roof, as found by reference to Tables XCV and XCVI, is considered as unity and the proportions for the other members are given in relation thereto. It will be seen from this diagram that it is recommended that a small shelter be constructed within the protective construction, leaving an air space over the roof and on the sides, the inner shelter resting on a layer of sand.

The object of this is to minimise the effects of concussion which occupants of the shelter would experience were the inner lining omitted. The proportions indicated on this diagram are to be taken as a general guide only, and are not intended to obviate the necessity of careful calculations. On the other hand, if these proportions are adhered to it will be found that in reinforced concrete construction adequate strength in all parts of the shelter can be obtained by the use of the appropriate amount of reinforcement. Fig. 220 shows details of reinforcement for a shelter constructed in reinforced concrete above ground level to give complete protection against direct impact of a 660 lb. medium case bomb. Attention is drawn to the fact that the reinforcement should be arranged in such a way as to facilitate the construction of the work in layers of 2 ft. maximum depth, and also that a soffit of steel in the form of permanent shuttering attached to the reinforcement must be used on the protective roof. An arrangement suitable is indicated on Fig. 221. Attention is also drawn to the fact that the bed of sand or gravel is retained in position by means of the bituminous mastic seal which fills the space between the external construction and the internal lining. There should not be hard structural contact between the lining and the

external construction as otherwise the concussion transmitted to the interior in the event of a direct hit would be such as seriously to injure the nervous health of the occupants.

The maximum damping effect would be obtained if the sand is composed of hard circular particles all of one size and not graded from fine to coarse and of angular form as is normal in sands used for the making of concrete.

The shelter can, of course, be rectangular, polygonal or circular on plan as may be desired, and the entrances and exits

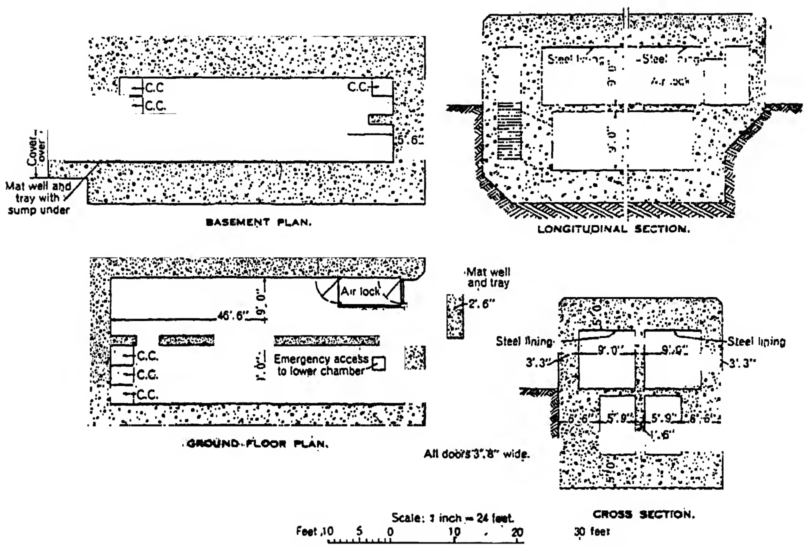


FIG. 223.—Design of a rectangular shelter for 200 persons, giving Class 6 protection.

(*Courtesy, Dr. Anderson and the Inst. C.E.*)

must be properly lined and arranged with a resilient connection where the passageway passes through from the external construction to the interior lining. The protection thickness for the roof is based upon the use of concrete having a crushing strength of 2,800 lb. per sq. in. at twenty-eight days, but economies in the construction can no doubt be secured by the use of concrete of richer mix, vibrated into position and having higher crushing strength. Special overstrained steels which have higher safe working stresses, such as Isteg steel, can also be used with advantage.

When dealing with the construction of shelters designed for

protection against direct impact too much emphasis cannot be laid upon the desirability of having a concrete with high tensile strength so that its shear resistance to penetration is thereby increased. In this connection it will be found that the use of a concrete with a low water cement ratio properly vibrated into position will give improved results.

For bombs having heavy cases or delay-action fuses, the thicknesses of the protection should be increased 50 per cent. in accordance with Table XCIV, p. 426. Furthermore, when

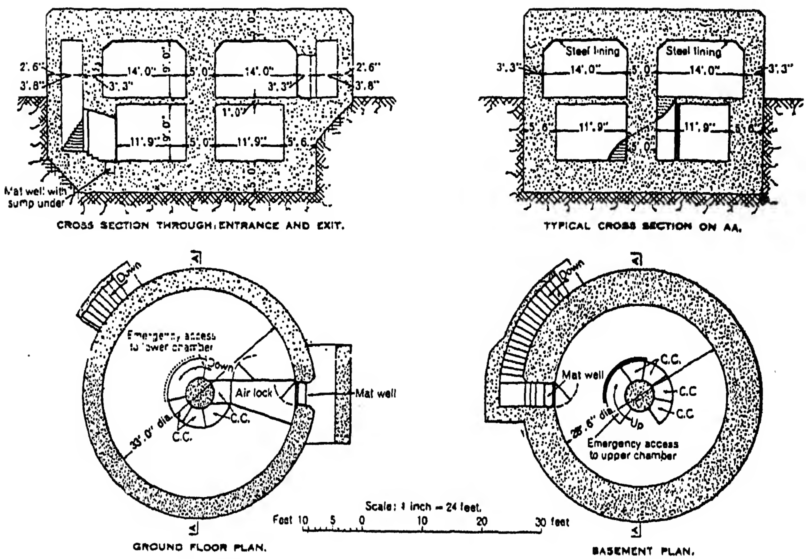


FIG. 224.—Design for circular shelter for 200 persons, giving Class 6 protection.

(*Courtesy, Dr. Anderson and the Inst. C.E.*)

large numbers of people have to be accommodated in such a shelter it is desirable for psychological reasons to increase the protection. The cost per head will be of the order of £25 to £35 per person, depending upon the size of the shelter.

Figs. 223 and 224 are reproduced by permission of the Council of the Institution of Civil Engineers and of Dr. Anderson, the author of a lecture on bomb-proof shelters.

They epitomise the recommendations of the panel of engineers set up by the Institution to examine and report upon the subject.

They recommend that protection against direct impact of 500 lb. medium case H.E. bombs striking at the maximum

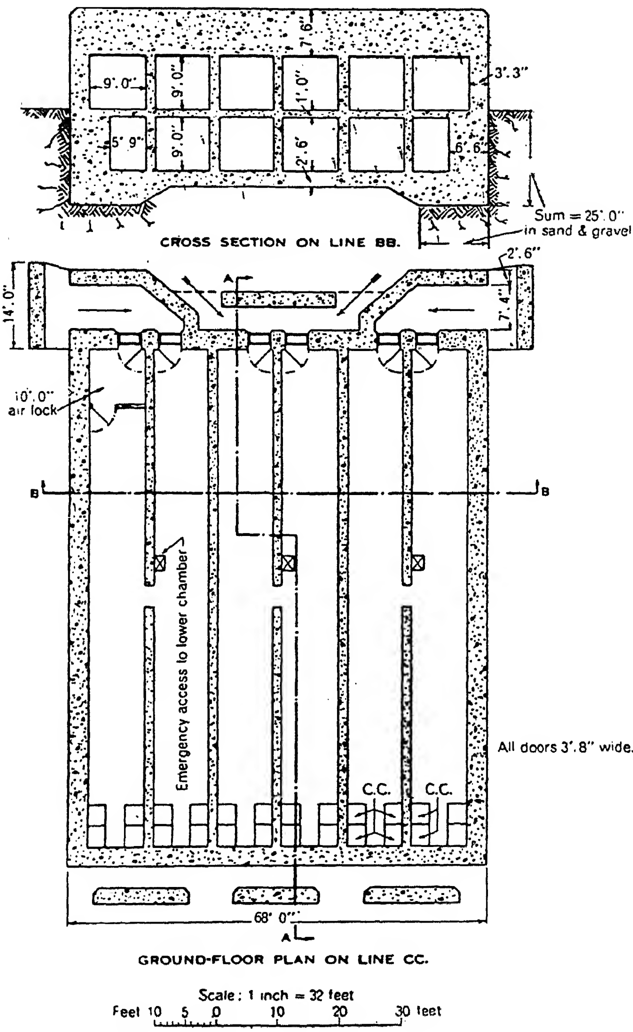


FIG. 225.—Design for a 1,200-person shelter, giving Class 6 protection.
(Courtesy, Dr. Anderson and the Inst. C.E.)

velocity would be suitable for strongholds to accommodate not more than 400 persons, that where the number of persons to be accommodated is greater than this the protective cover

be increased 50 per cent. equivalent to protection against 500 lb. heavy case bombs.

They further recommend that the maximum number of persons to be accommodated in one shelter should not exceed

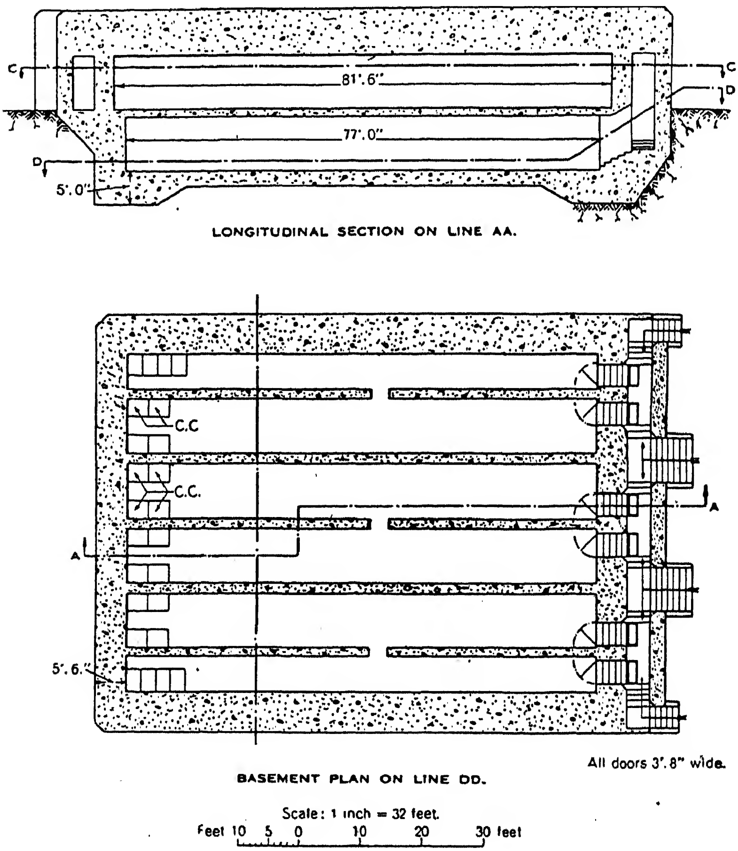


FIG. 226.—Additional views of shelter shown in Fig. 225.
(*Courtesy, Dr. Anderson and the Inst. C.E.*)

1,200, and that the shelters be divided into compartments so arranged that each would hold about 100 persons.

Figs. 225 and 226 show the recommended arrangement of a 1,200-person shelter designed on the above lines.

In view of the fact that it is desirable to carry the side walls well down to secure adequate lateral protection, accommoda-

tion in ground floor and basement can be provided economically. Fig. 227 shows the recommended arrangement of reinforce-

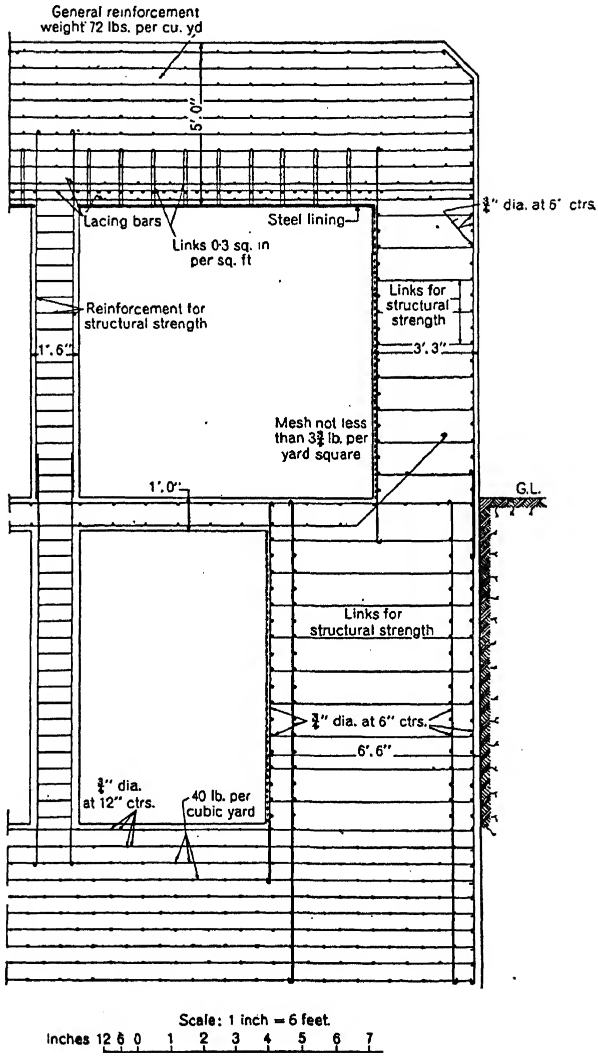


FIG. 227.—Showing details of the steel reinforcement of the roof and side walls of bomb-proof shelter, giving Class 6 protection.
(*Courtesy, Dr. Anderson and the Inst. C.E.*)

ment, the concrete being of 1–1½–3 mix and having a crushing strength of 4,000 lb. per sq. in. at twenty-eight days.

It is evident that as the depth of multi-storey shelters is increased the thickness of the side walls can be reduced progressively.

The Committee recommend that after a depth of 25 ft. below ground in the case of sand or gravel and 40 ft. in the case of clay, the thickness might be reduced by 4 in. for every additional foot in depth, the minimum thickness being 2 ft. 6 in. or that required for structural stability, whichever is the greater. Fig. 228 shows a method of using pressure piling

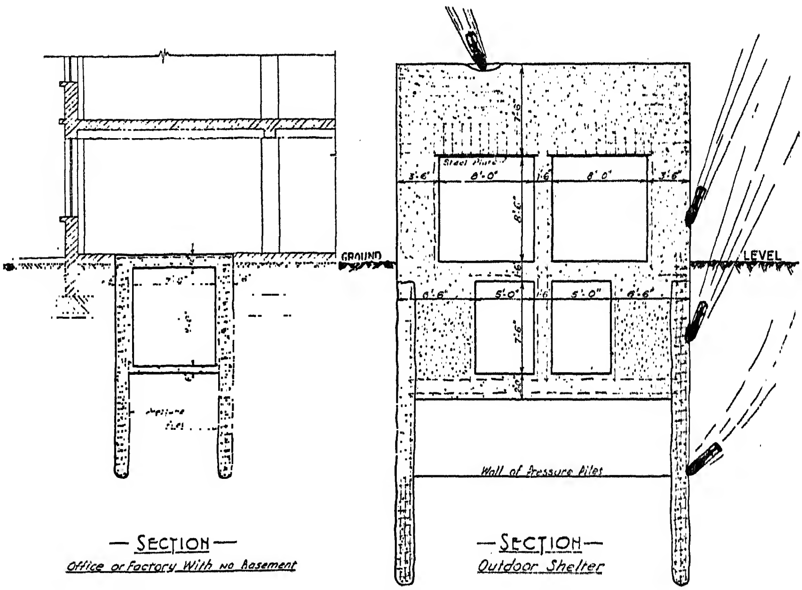


FIG. 228.—Lateral protection by the use of pressure R.C. piling.

in construction of bomb-proof shelter so as to afford lateral protection.

With regard to cost, after considering thirty-three designs in all, the Committee abandon the "umbrella" construction (using an extended apron or burster slab) and the "sandwich" constructions as not so economical as the solid types illustrated.

The estimated cost of large shelters for 1,200 people, as given by Dr. Anderson, works out to £17 10*s*. per person, the rectangular shelter for 200 people, £25 10*s*. per head, and the circular shelter £21 10*s*. per person.

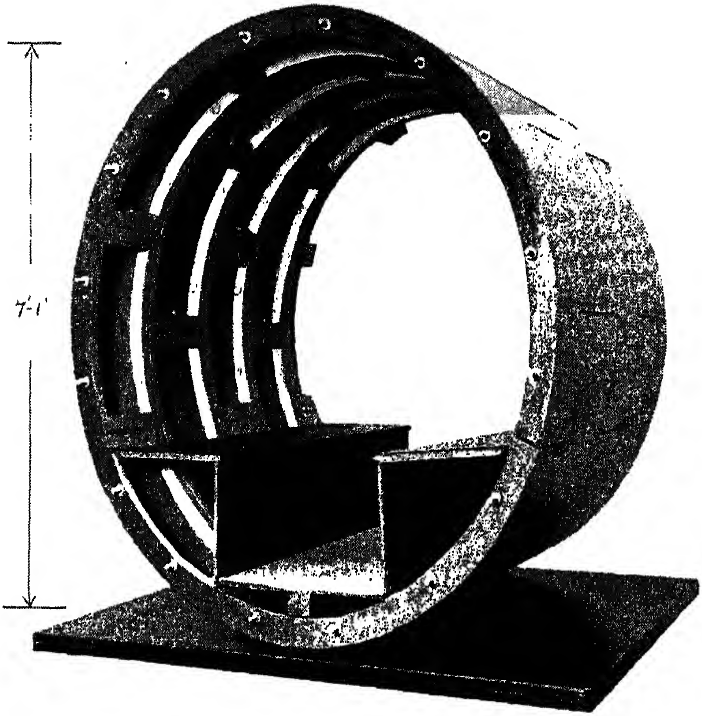


FIG. 229.—Photographic model of a Shockcrete-segment tunnel.
(Courtesy Richard Costain Ltd. and L.P.T.B.)

[*To face page* 446.

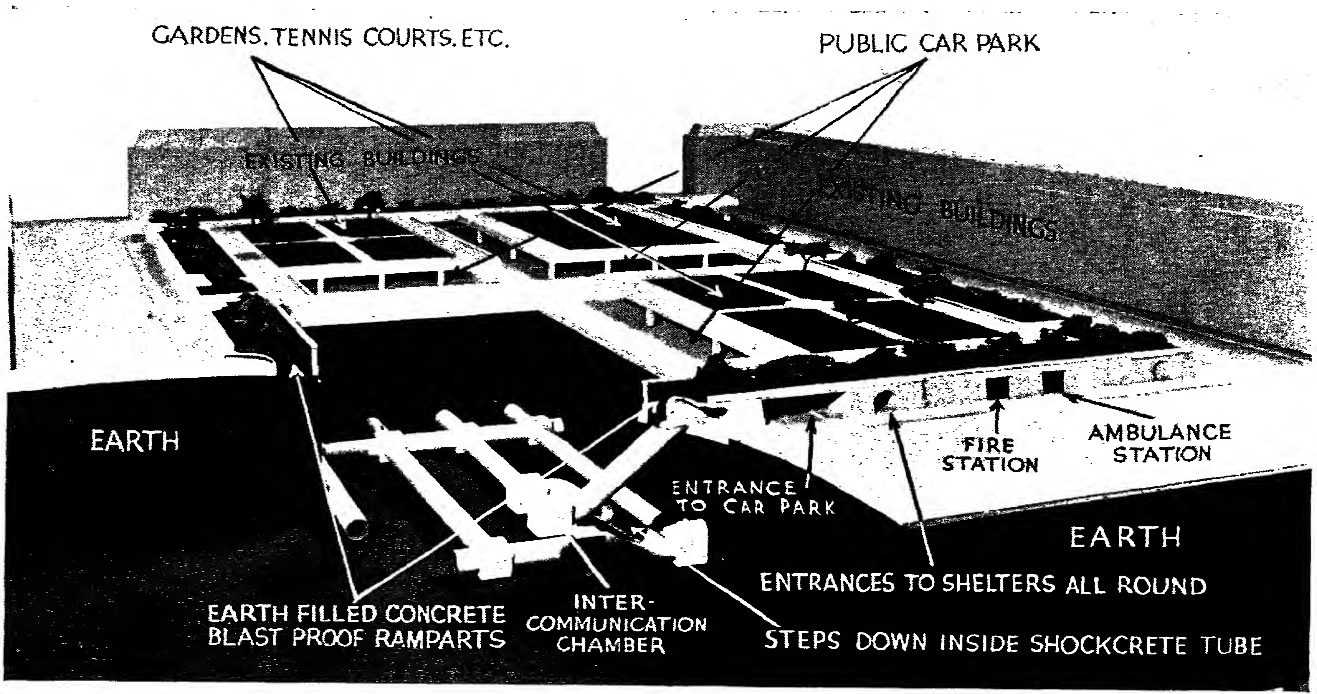


FIG. 230.—Model showing tunnel shelters under public gardens, tennis courts, etc., raised to roof a public car park.

(*Courtesy Richard Costain Ltd. and L.P.T.B.*)

DEEP SHELTERS

Deep shelters have often been advocated, but, in designing the shelters, depth required for immunity should be calculated on the basis of the capacity of the buried structure to resist the forces of subterranean explosions. As already pointed out on p. 446, the nearer the surface the heavier the construction is required to be. There is, of course, an irreducible minimum for the thickness of construction required for ordinary structural reasons, however deep the shelter may be constructed. The condition of the ground and the circumstances appertaining during the construction of the shelter all have a dominating influence upon the design adopted.

Deep Tubular Shelters

The deep system of shelter construction using shockcrete pre-cast tubes or tunnel segments, as illustrated in Figs. 229 and 230, has much to commend it. Such a scheme incorporates not only a solution to the car parking problem, but at the same time provides an earning power which could be set against the cost of the deep shelter A.R.P. system beneath. Utilisation of the excavated earth for filling of the concrete bastion surrounding the square provides a blast- and splinter-resisting protection for the surface buildings, which could be utilised as auxiliary fire stations, dressing centres, entrances to shelters, etc. The material is obtained from Messrs. R. Costain Ltd. in the form of circular tubular linings or tunnel segments tested to over 7,000 lb. per sq. in. direct stress. The system of construction provides for the internal bolting of the segments, thus enabling rapid and efficient erection to be carried out. The provision of a bitumen-dipped cord for the jointing, coupled with the use of spring-washered bolts, renders the joints proof against surface water percolation and possesses a certain resilience desirable in construction of this kind subject to vibration or shock. It is claimed that in the construction of the extension of the London Passenger Transport Tubes a saving of some 60 per cent. on the cost of heavier cast iron segments originally used was made.

Tubular linings made of the same material are in the form of a complete ring having an outside diameter of 7 ft. 6 in.,

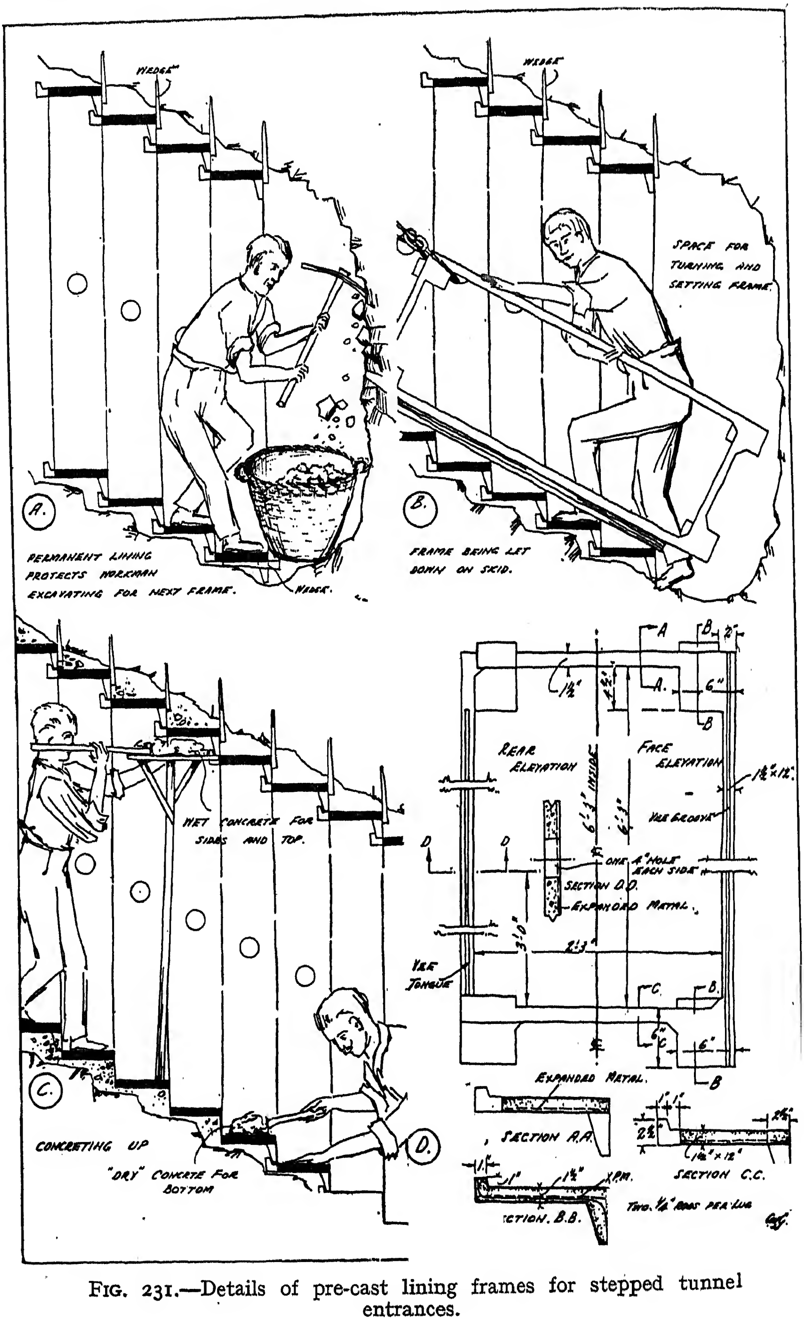


FIG. 231.—Details of pre-cast lining frames for stepped tunnel entrances.

inside 7 ft. 2 in., the internal diameter of the bolting ring being 6 ft. 8 in. and the weight 4 cwt. per section. Radial sections are available, permitting of adaptation for entrances, curves, etc. These tubular linings are, however, recommended for the more shallow type of shelter buried no more than 17 ft. below the surface and covered as necessary with protecting slabs or deflectors at ground level.

STEPPED ENTRANCES FOR TUNNEL SHELTERS

Except in the hands of experts, the construction of stepped entrances to tunnel shelters is an exceedingly difficult operation. Fig. 231 indicates how pre-cast reinforced concrete lining segments can be used with advantage.

It will be seen from these illustrations that as soon as the work of excavation in the heading has proceeded some 3 ft. beyond the last placed section, there is ample room for a new one to be wedged into position by two men and an interlocked lining is thus immediately produced. The grouting operation is as shown in the illustrations. By the use of such pre-cast units, no temporary timbering will be necessary, since the linings themselves designed on the rigid frame principle afford the necessary protection during the progress of the work.

Rectangular sectional entrances are the best, and if the width is no more than half the height there will be no difficulty experienced in carrying the sections through the completed tunnel as required.

LARGE DEEP SHELTERS

Fig. 232 shows a proposed shelter designed by Tecton for the Finsbury district. The main criticism that has been directed against such deep shelters is that it would be dangerous to concentrate so many people in one spot, that panic might ensue when people rushed to the entrances, that people would be tempted to remain an unnecessarily long period in the shelters, and also that too many people would have far to travel to reach them. Construction of such dual purpose shelters has, however, much to commend it, especially if they are of somewhat smaller dimensions and widely dispersed throughout the Metropolis. The Finsbury scheme represents the first attempt in this country to provide bomb-proof protec-

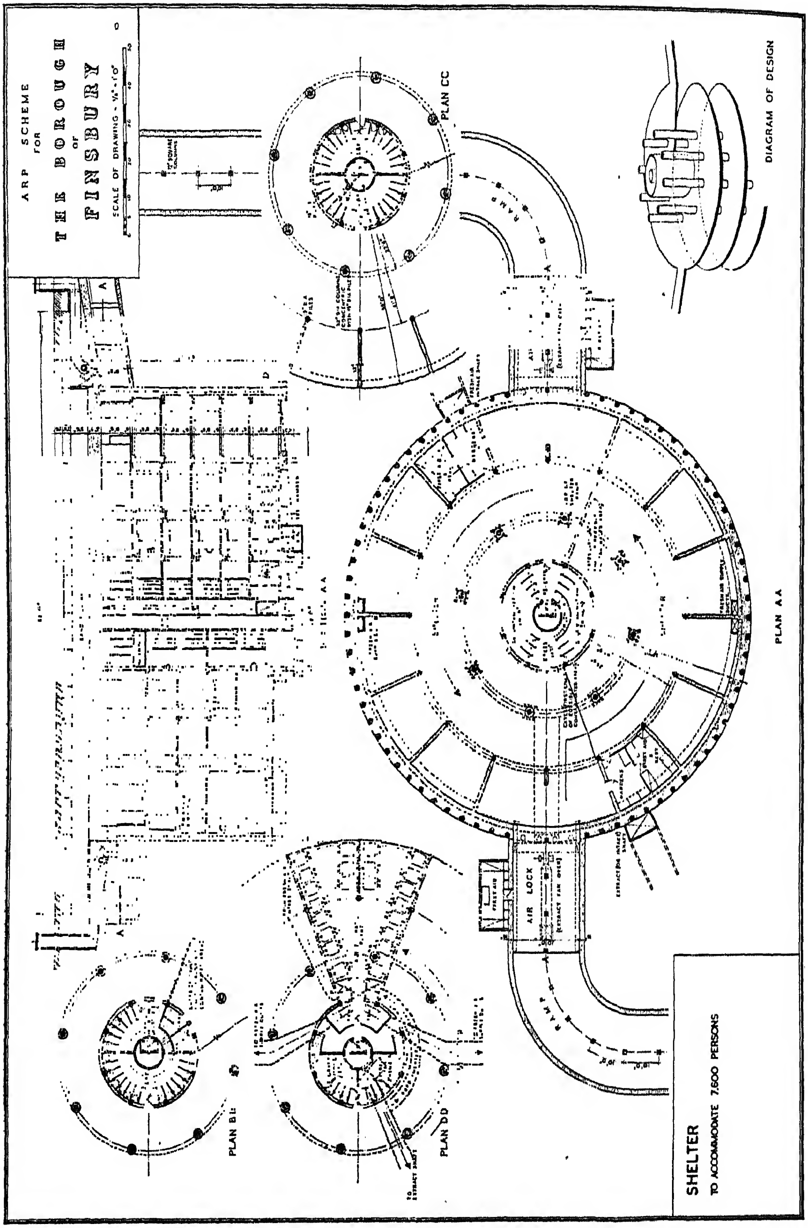


FIG. 232.—Design by Tecton for deep shelter for 7,600 persons.

tion for the public, but for the reasons already stated such provision for more than Class 5 protection for the general public has not been officially encouraged. It is true that Class 6 protection may be provided in control centres in municipal A.R.P. schemes, but these are comparatively small shelters accommodating possibly not more than 100 persons at one time.

The Finsbury scheme provides for protection in bomb-proof shelters for the entire wartime population of the Borough, and involves the construction of no less than thirty shelters, varying in capacity from 7,600 persons in the smallest to 12,600 in the largest.

Fig. 232 shows a shelter of the smaller capacity. It is circular on plan with a diameter of 120 ft., and is of multi-floor construction with ramped passages for entrance and exits and inter-floor connections. The roof slab is designed to give protection against direct hit by ½-ton bombs, and is, of course, easily increased in thickness to resist bombs of heavier calibre. The roof is of the sandwich construction, but from what has already been said it will be evident that economies could be effected by increasing the thickness of the roof slab itself and doing away with the burster course. It is calculated that the 7,600-person type of shelter will accommodate 150 cars. The cars could easily negotiate the spiral ramp, which has an outside diameter of about 80 ft., excluding the portion which is sub-divided by baffle walls. The system of construction devised by Mr. Ove. N. Arup is an ingenious one.

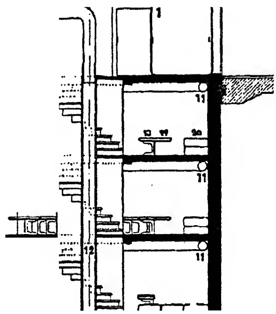
Excavation is first carried out over the entire area of the shelter down to the depth of the soffit of the top protection. Reinforced concrete piles are then placed in position on the centre lines of all the columns in the construction. The top slab is then concreted on the ground and excavation continued underneath it down the spirals from floor to floor, each floor being cast on the excavated ground surface as the work proceeds. A hole is, of course, left in the centre of the roof slab for the removal of excavated material, and this is afterwards filled in.

When the slab has set excavation proceeds beneath it, exposing the piles, which then function as columns supporting the floor slabs. The whole process is a continuous one until

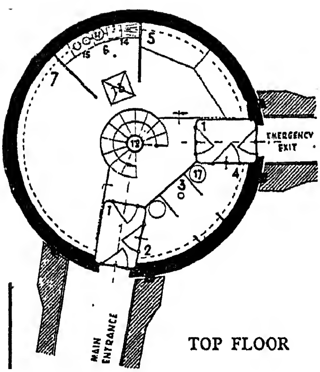
the bottom level is reached, the outer walls are constructed as the work proceeds, and when the whole structure has been carried downwards to the required depth the piles are encased with additional concrete, so that they will safely support the superimposed loads on the floors and the considerable weight of the sand layer and detonating slab which are then put in position on top of the roof. It is claimed that by this method of construction practically all shoring and shuttering is eliminated, and also that once the top slab is cast the work is able to proceed independently of weather conditions. It is estimated that the shelter could under normal working conditions be completed in eight months, and that the cost of the structure, exclusive of ventilating and other equipment, is estimated at £6 per head if ½-ton bomb protection is provided, and only £7 4*s*. per head if the protection is increased to resist 1-ton bombs. It is further claimed that a shelter of the type described, complete with protection against a ½-ton bomb and with all mechanical equipment, would cost no more than £10 10*s*. per head.

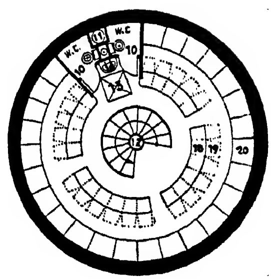
Fig. 233 gives general details of the Schindler stronghold, which was described by Mr. C. F. de Steiger, F.A.R.P.I., in his paper before the General Meeting of the Institute on November 8th, 1938. As will be seen from the illustration, this stronghold is sunk below ground level, the entrance being effected by tunnels either from the open or from neighbouring buildings. The shelter will be seen to contain four floors, the various sections being reached by a central staircase around the central waste air chimney. In constructing the stronghold, the ground is excavated to the depth of the intended earth cover over the completed structure and the lowest storey of the external walls is then formed in *in situ* reinforced concrete with a cutting edge on the bottom. Excavation then proceeds within the protection of this ring and the external wall gradually sinks down to its correct level; additional concrete being applied to the wall within sliding shuttering as the sinking process proceeds.

When the external wall is in its final position the inverted dome at the base is concreted on the excavation shaped appropriately to receive it. The floors are then constructed, leaving the spaces indicated on the drawing, and utilised



SECTION





PLAN

TOP FLOOR

LOWER FLOOR

(1) Air Lock
(2) Undressing Room
(3) Shower
(4) Dressing Room
(5) Hospital
(6) Kitchen
(7) Plant
(8) Fresh Water Tank
(9) Waste Water Sump
(10) W.C.
(11) Fresh Air
(12) Waste Air
(13) Trap Door
(14) Sink
(15) Cooker
(16) Lav. Basin
(17) Hot Water Boiler
(18) Bench
(19) Tip-up Seat
(20) Mattresses

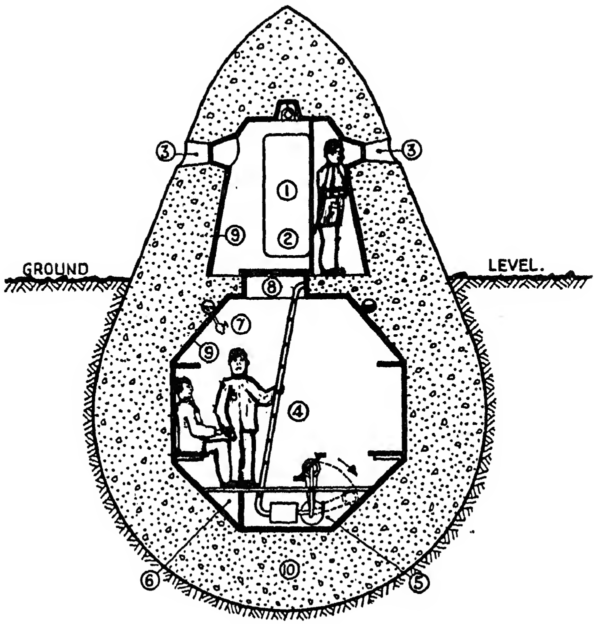
SCHINDLER STRONGHOLD

(STANDARD TYPE)

FIG. 233.—Details of the standard type of Schindler stronghold.

(*Courtesy A.R.P. Inst.*)

respectively for water sumps, tanks, etc. The cost of constructing a standard Schindler stronghold for 200 people amounts to £15 to £20 per head. The smallest type of Schindler



①	ENTRANCE, GAS LOCK & OBSERN POST.	⑥	SPARES, TOOLS ETC.
②	GAS PROOF STEEL DOOR.	⑦	WATER SUPPLY 15 GALLONS.
③	OBSERVATION PEEP HOLE.	⑧	MANHOLE WITH GASPROOF COVER
④	SHELTER ROOM, 12-16 PEOPLE.	⑨	GUNITE OR STEEL SHELL.
⑤	VENTILATION PLANT & FILTER.	⑩	REINFORCED CONCRETE.

SCHINDLER STRONGHOLD
(SMALLER TYPE)

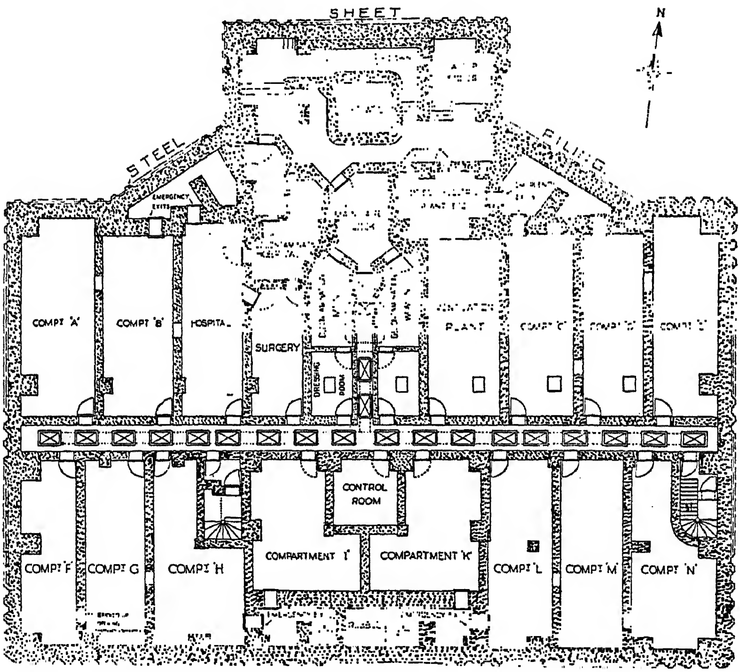
FIG. 234.—Small Schindler surface bomb-proof shelter.
(*Courtesy A.R.P. Inst.*)

stronghold, combining a conical shape above ground and a spherical shape below ground, giving an equal resistance all round, has been evolved and is illustrated in Fig. 234. These shelters are made with permanent steel forms inside to accommodate twelve to fifteen people, and are said to cost approxi-

mately £32 per person accommodated. This price is including permanent steel lining, reinforced concrete work and all installations.

STRONGHOLDS IN NEW BUILDINGS

Figs. 235, 236 and 237 give a general outline showing the construction of the stronghold installed below the tower of the



PLAN OF STRONGHOLD: SIMMONDS AEROCESSORIES, LTD.

FIG. 235.—Plan showing arrangement of stronghold under tower of factory building on Great West Road, London.

(*Courtesy A.R.P. Inst.*)

factory for Messrs. Simmonds Aerocessories Ltd. on the Great West Road. The architects for the building were Messrs. Wallace Gilbert and Partners, and the consulting engineer for the reinforced concrete design was Mr. C. F. de Steiger, F.A.R.P.I. The work was carried out by Messrs. John Laing & Sons Ltd. It will be seen from the section that the 8 in.

reinforced concrete floor, described as the main floor, is designed to deal with the collapse of the building, and therefore affords Class 5 protection for employees or the public admitted to the space between it and the stronghold below.

The stronghold is constructed under the tower of the building, which comprises nine floors and which would therefore afford considerable protection to the stronghold beneath. Sheet piling was used to enable the footings to be carried down to the blue clay 20 ft. below ground level and some 18 ft. below normal standing water level in the land.

The arrangement of the shelter is as shown on the plan reproduced in Fig. 235, from which it will be seen that the external walls are 2 ft. 6 in. and 2 ft. 9 in. thick, the internal walls 1 ft. 6 in. thick supporting a roof 2 ft. 6 in. thick. All concrete is reinforced in three directions and vibrated into position, the general arrangement of some of the reinforcement being shown on the photograph reproduced in Fig. 257. A description of this stronghold was given by Mr. G. R. Falkiner Nuttall, M.A., A.M.Inst.C.E., in his paper on "The Planning of Shelters in Buildings for A.R.P.," given before the Air Raid Protection Institute on October 11th, 1938, and readers are referred to this paper for further information. The stronghold provides in all for the accommodation of 1,000 people, and the cost is approximately £20,000 complete with equipment.

DUAL PURPOSE STRUCTURES

Garages

Proposals have been made from time to time that underground car parks or garages should be constructed in such a way as to provide accommodation for the public as air raid shelters, and in most cases hitherto it has been found difficult to justify the expenditure on economic grounds in peace time. In the case of public garages it will be found that the necessity for quick service and the avoidance of congestion and the reduction in handling costs necessitate the retention of a certain amount of free manœuvring space, and as a result it will be found that the various arrangements of floors and inter-floor connections require the following approximate gross area per car accommodated :—

TABLE XCVII

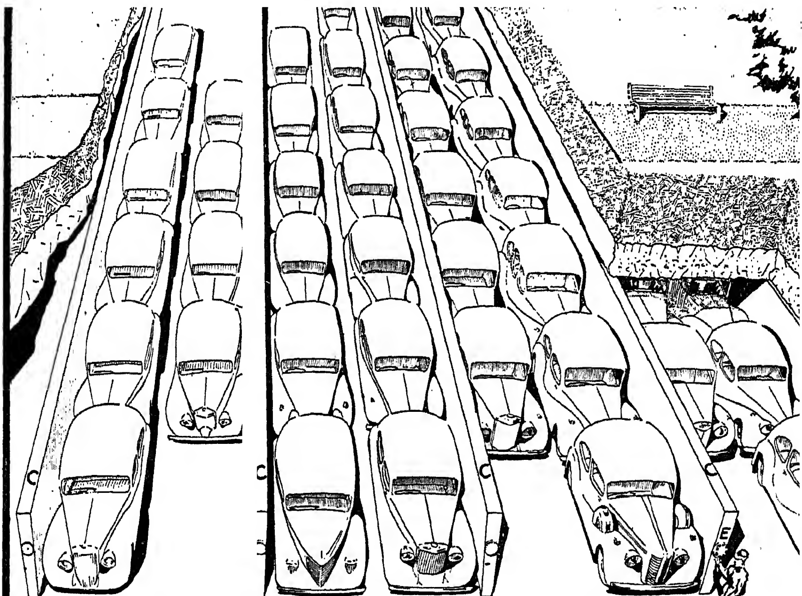
Straight one-way ramp system	242 sq. ft. per car.
Straight two-way ramp system	290 ,, ,,
Staggered floor system	218 ,, ,,
The elliptical ramp system	278 ,, ,,
Spiral ramp system	260 ,, ,,
Double spiral ramp system	243 ,, ,,
Spiral garage	230 ,, ,,
Circular garage with mechanical turntable	150 ,, ,,
Traverser floors	180 ,, ,,

It will therefore be seen that one way of securing the maximum accommodation in a given area is to utilise mechanised parking.

In connection with the Baldwin-Auger mechanised system a survey has recently been made of a great number of sites suggested as suitable for dual-purpose structures, and it has been found that in a large proportion of the sites examined conditions prevailed which permit undertakings to be financially sound. It may safely be said that there are in the congested traffic areas of London and the principal cities and towns of the United Kingdom some 600 sites which could be economically developed in this manner. Fig. 238 indicates pictorially the Baldwin-Auger mechanised parking system, and it will be seen from this illustration that the cars are parked on longitudinal conveyors, there being cross-traversers at the ends. The car is placed on the conveyor at the service end, and the engine is then stopped and is not required to be started again until it is brought automatically to the end of the conveyor when required to be driven away. The illustration shows an attendant dialling the appropriate number for the car to be brought to the end. The operation is for the right-hand conveyor to move forward and the left-hand conveyor to move backwards; the cross-traverser at the end coming into operation as required and the whole mechanism stopping when the appropriate car is brought to the end ready for removal. It will be seen that by this special arrangement the supporting walls " C " can be as close as 15 ft. c/c, thus providing adequate support for the roof, which can be of any desired thickness to give the degree of protection called for. The arrangement also

automatically divides the interior of the garage into a number of segregated compartments, which in an emergency could well be used as shelters.

Fig. 239 shows a typical plan; the part above the centre line shows the underground space arranged as a mechanised car park and the lower part of the plan shows the same structure



Although mechanised, the floor pr ı flush surf y normal garage. Push buttons actuate the mechanism by means of which elected automatically brought to the delivery point adjacent to the throughway, and is ready for driving away. This rearrangement of the cars is entirely confined to the floor space upon which the cars are actually parked, and does not involve the use of any additional space whatsoever, even though the bay is packed to capacity.

FIG. 238.—Pictorial representation of the Baldwin-Auger Parking System.

arranged as an air raid shelter. The car park accommodates 171 cars, and when adapted as a shelter provides protection for 3,300 people on a basis of 6 sq. ft. of floor area per person. Each bay would accommodate nineteen cars and the mechanism can deliver a car every thirty-two seconds to the through-way.

One attendant can operate five bays (ninety-five cars) without leaving a beat of 25 yards. There is no driving except on the through-way. Once a car has been parked it is not

approachable by any driven car, and is therefore safe from damage. Regarding the operational economies, it is claimed that there is a reduction in the illuminated area, a reduction in the ventilated area, a reduction in the operating staff, minimised fire risks, freedom from accidents and a very considerable saving in handling time. It is claimed that

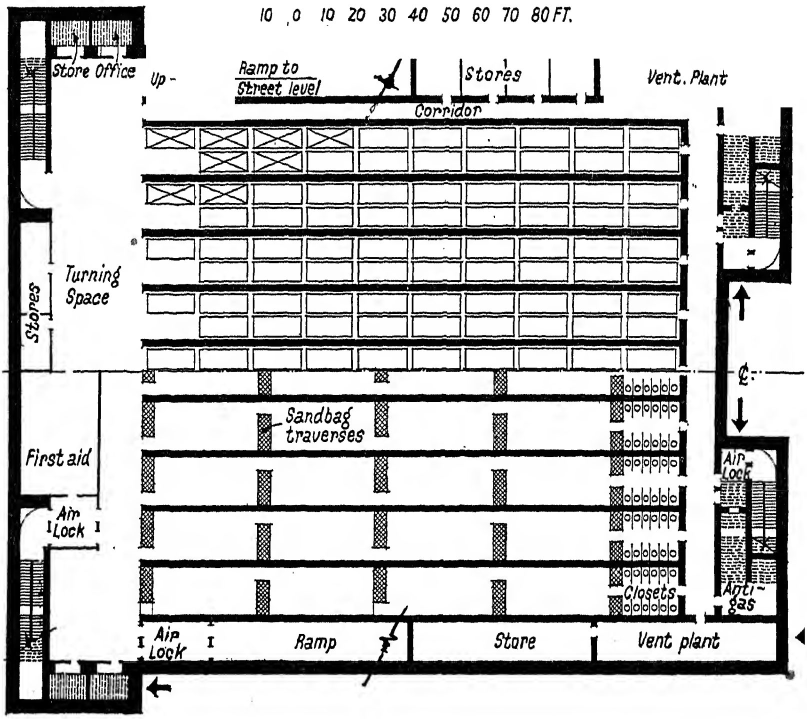


FIG. 239.—Typical plan of garage with mechanised parking—*above centre line*, arranged as a garage—*below centre line* arranged as a shelter.

compared with conventional methods the Baldwin-Auger system gives speedier and safer parking at a lower operational cost.

In respect of financial economies for the system, it is claimed that the structural cost per car and operation expenses have been reduced to a figure which can be covered by earnings, and that capital can therefore be obtained from ordinary investment sources without imposing a charge upon the taxpayer. As an example, it may be stated that a car park under Leicester

Square on a conventional arrangement would accommodate no more than 200 cars, but as a mechanised park it would take 350. In round figures the revenue from 350 cars at $2\frac{1}{2}d.$ per hour would be £3 13*s.* per hour, or, say, £40 per day of twelve hours—over £12,000 per annum. The cost of operating would be 40 per cent., making a nett return of over £7,000 per annum. The capital cost of the Class 6 bomb-proof structure would be of the order of £135,000, interest on which at 5 per cent. would be £6,750. It is claimed that this form of structure has one peace-time purpose—in the relief of traffic congestion by which the revenue derivable would service the cost of operation on the capital cost of construction, and also it would offer two possible purposes in war-time :—

1. As a shelter for personnel.
2. As a reservoir for water.

Should the demand for a reserve supply of water be considered more important than the provision of a shelter for personnel, it would be easy to flood the structure to a height of 8 or 10 ft. from the floor, and the structure could then be made to hold some 6,000,000 gallons of water, as a local reserve for the prevention of fires caused by incendiary bombs and for general domestic use if the normal service fails to function. In this case it would only be necessary for water-tight gates to be installed in an emergency at the ends of the bays, so that a number of separate reinforced concrete tanks would thus be provided, and if some of these were damaged the whole contents of the reservoir would not be lost. There is no doubt that this type of structure offers very considerable scope for development, and it is interesting to note that an underground car park cum shelter has been constructed in Cardiff with this mechanised system installed. The shelter will be used for a car park, above which gardens will be laid out, and is situated in the centre of the new Civic Square.

This car park accommodates 500 cars and will provide shelter for up to 3,000 persons. Essential services as required by the municipality are installed, and ordinary access and egress is by means of ramps which are provided with air-locks at the corners, whilst emergency ladder escapes are provided on the three sides. The architect for the work was Mr. Sydney

Clough, F.R.I.B.A., and the contractors Messrs. B. Sunley & Co. Ltd.

HOSPITALS

Provision of at least Class 6 protection to a large part of the accommodation in city hospitals will sooner or later be necessary, and Fig. 240 shows the author's suggestion in this

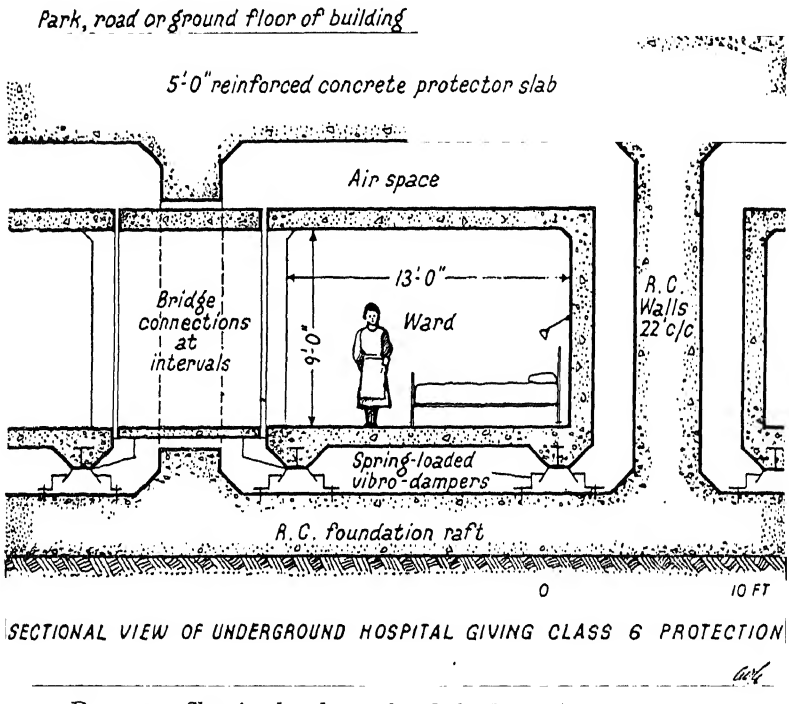


FIG. 240.—Showing bomb-proof and shock-proof hospital ward.

connection. There seems to be little point in providing structural protection against the impact of a ¼-ton bomb if there is no provision made for the elimination of the vibration and noise which would accompany such impact. There is no doubt that the concussion brought about by direct impact of a high explosive bomb on a shelter would cause very serious nervous shock to the occupants, and in any hospital accommodated in a bombed area it is, in the opinion of the author, very

necessary to make provision for the elimination of the shock of concussion.

It will be seen from the sectional view of the underground hospital given in Fig. 240 that it is suggested the whole of the interior construction of the wards be supported on spring-loaded vibro dampers. This is not by any means a difficult problem, as standard appliances at present used for the elimination of vibration from engine beds could easily be utilised. It will also be seen from the sketch that the air space all round the inner construction has been somewhat increased from the proportions given in Fig. 219 in order to provide access to the vibration damping devices. The top of the protector slabs

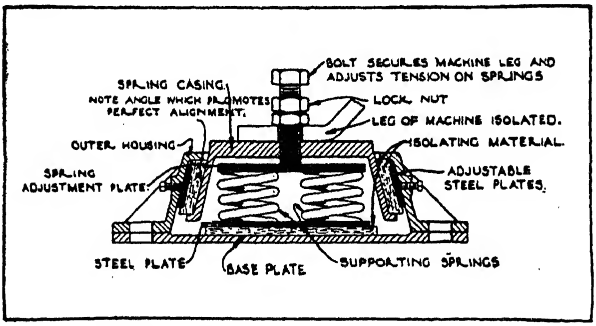
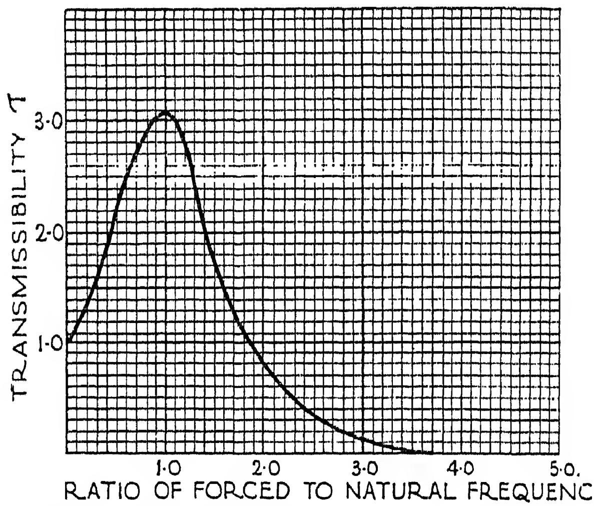


FIG. 241.—Section through spring isolator.

could quite well form the ground floor of a building, a road surface, car park or could support 4 or 5 ft. of earth in public gardens. The construction is simple, there being reinforced concrete supporting walls at 22 ft. c/c pierced at intervals for bridge connections between the wards. Assuming beds are installed in wards 13 ft. wide at 7 ft. c/c, the approximate cost of the structure would work out at £400 per bed. Many of the most distinguished physicians and surgeons in this country have expressed the view that to prevent a complete breakdown of the medical organisation in war-time raid-proof clearing stations must be constructed, and Fig. 240 indicates one way in which this might be accomplished.

Fig. 241 gives sectional details of a suitable spring-isolator, in which the housing of the damping device is fixed independently to the foundations.

Fig. 242 shows the relation between the transmissibility and the frequency ratio. From this it will be seen that when the ratio of forced to natural vibrations is 1, *i.e.*, when the natural frequency of the load on its elastic support corresponds with that of the vibration to be isolated, a condition of resonance obtains, and the vibration transmitted will be three times that



GRAPH SHEWING THE RELATION BETWEEN THE TRANSMISSIBILITY & THE FREQUENCY RATIO.

NOTE: MOST MACHINE 'FORCED' VIBRATIONS ARE BETWEEN 80-160 CYCLES/SEC

FIG. 242.

of the load resting direct upon the foundations without an isolator.

It will also be seen that when the frequency ratio is 3 or more, there will be very little of the forced vibration transmitted through the device.

Earth tremors as a result of bomb bursts are expected to be similar to those brought about by seismic effects, and may be anything between 10 and 30 cycles per second. It would therefore be desirable to load the vibration-isolators to a natural frequency of 1 to 2 cycles per second in order to ensure shock elimination.

CHAPTER XII

THE STATUTORY BASIS OF A.R.P.

Generally

The Government's policy for protection of the civil population against the hazards of aerial bombardment is laid down in the many official publications referred to in this volume and enumerated in Appendix IV.

The statutory obligations imposed upon local authorities, landowners and employers to provide certain standards of protection and the terms upon which grants will be made towards the cost are matters which can only be understood by a study of the principal provisions of the Air Raid Precautions Act of 1937, the Fire Brigades Act of 1938, and the Civil Defence Act of 1939, together with any statutory regulations or bye-laws drawn up under them.

It is therefore the author's endeavour in this chapter to draw up a concise reference to the Government's shelter policy, both as regards technical requirements and legislation.

The Government have decided that Class 5 protection would best suit the conditions in this country, and have only conceded the desirability of providing Class 6 protection in special cases, such as in the construction of A.R.P. control posts in evacuation areas.

The code lays down the standards of protection and the Government have made provision for financing such protective measures.

Lower standards than those prescribed will not qualify for grant, neither will the grant be increased to include the cost of the provision of a standard of protection higher than that laid down.

There is, of course, nothing to prohibit the construction of standards higher than the minima specified or to prevent official revision of the code at present laid down.

Work to qualify for grant must have been commenced by September 30th, 1939.

THE AIR RAID PRECAUTIONS ACT, 1937

An Act to secure that precautions shall be taken with a view to the protection of persons and property from injury or damage in the event of hostile attack from the air. 22/12/37.

DIGEST

FUNCTIONS OF LOCAL AUTHORITIES

SECTION **1.—Duty of certain Local Authorities to prepare and submit Air Raid Precaution Schemes**

(1) (2) County Councils are to prepare Air Raid General Precautions Schemes in collaboration with local district councils; but with the approval of the Secretary of State. Borough or Urban District Councils may prepare such schemes for their districts.

(3) Air raid fire precautions schemes are to be submitted to the Secretary of State by Borough, County Borough and Urban Councils, but Rural Councils may also submit air raid fire schemes.

(4) The Secretary of State will prescribe what matters are to be included in schemes and may dispense with submission of schemes relating to any particular matter.

(5) Separate schemes for different matters or for different areas may be submitted or may be required.

(6) A council having submitted a scheme may arrange with another council—also required to submit a scheme—to carry out the functions as an agent.

(7) Any scheme may make provision for some expenditure to be dealt with as special county expenditure.

SECTION **2.—Application of Section 1 to London**

(1) Section 1 to apply to the Administrative County of London subject to the Secretary of State allocating matters for schemes to the L.C.C., the Common Council of the City, and the Metropolitan Borough Councils.

(2) In London the L.C.C. will deal with the air raid Fire Scheme.

(3) The Common Council of the City of London is to be

included with the Metropolitan Borough Councils under Section 47 of the Local Government Act, 1933, for the purpose of carrying out the functions under the A.R.P. Act, 1937.

SECTION **3.—Approval, Effect and Amendment of Air Raid Precaution Schemes**

(1) Approved or amended schemes take effect from the date provided therein.

(2) Local authorities must discharge their duties under approved schemes.

(3) Any scheme may be amended by re-submission.

SECTION **4.—Duty of Local Authorities to Co-operate and Power to Act Jointly**

(1) Local authorities must co-operate but not form joint committees or delegate functions unless with express approval of Secretary of State.

(2) The Secretary of State may direct formation of joint committees.

SECTION **5.—Compulsory Purchase of Land**

Local authorities may order compulsory acquisition of land for A.R.P. purposes if confirmed by Secretary of State.

SECTION **6.—Duty of Local Authorities to Assist in Arrangements for Evacuation**

Local authorities to furnish Secretary of State any local information required in preparation of Government scheme for evacuation.

FINANCIAL PROVISIONS

SECTION **7.—Expenditure by Local Authorities**

(1) Any local authority may incur expenditure on A.R.P., whether or not covered by submitted scheme.

(2) Any such expenditure since July 9th, 1935, deemed lawfully incurred under the Act.

(3) Metropolitan Borough Councils may borrow money for A.R.P. under this Act with the sanction of the Ministry of

Health, and not the L.C.C., except where expenditure relates partly to works for which money is borrowed with L.C.C. consent under some other Act.

SECTION **8.—Exchequer Grants**

(1) Grants will be made by the Treasury as laid down in the Schedule (para. 1), *infra.*

(2) Grants paid subject to audit.

SECTION **9.—Expenses payable out of Moneys provided by Parliament**

Expenses incurred by Secretary of State with consent of Treasury on performing all functions covered by this Act will be provided by Parliament.

SECTION **10.—Investigation of Working of Financial Provisions**

The Secretary of State will, before December 22nd, 1940, examine the financial arrangements, particularly in relation to local rates, and report to Parliament.

SUPPLEMENTARY

SECTION **11.—Regulations and Orders by the Secretary of State**

(1) Secretary of State with concurrence of Treasury may make regulations providing for equipment, loans, gifts or sales and for approval of local expenditure.

(2) Any order by the Secretary of State may be varied or revoked by a subsequent order by him.

(3) Parliament may confirm or annul any such order within twenty-eight days.

SECTION **12.—Interpretation**

Defines "approved expenditure" as that part of local authority expenditure approved by Secretary of State under this Act, and "Local Authority" as including any authority having power to levy a rate.

SECTION **13.—Application to Scotland**

Modifications of the Act so as to apply to Scotland.

SECTION **14.—Provisions as to Northern Ireland**

Confirms that Parliament of Northern Ireland has power to make laws for A.R.P.

TABLE XCVIII

SCHEDULE TO THE A.R.P. ACT, 1937

CALCULATION OF EXCHEQUER GRANTS TOWARDS APPROVED EXPENDITURE

Weighted population. / Estimated population.	Percentage of Approved Expenditure paid by Exchequer to County Councils, County Boroughs and County Districts.	
		If Balance greater than 1d. rate, additional grant.
Up to 1·5 . . .	.60 per cent.	75 per cent. of balance.
1·5–2·5 . . .	65 ,,	,, ,,
2·5–4·0 . . .	70 ,,	85 ,, ,,
Exceeding 4·0 . .	75 ,,	,, ,,
	Percentage paid to City of London and Metropolitan Boroughs	
		If Balance greater than 1d. rate, additional grant.
Up to 1·25 . .	60 per cent.	75 per cent. of balance.
1·25–1·50 . .	65 ,,	,, ,,
1·50–1·75 . .	70 ,,	85 ,, ,,
Exceeding 1·75 .	75 ,,	,, ,,

THE RATING AND VALUATION (AIR RAID WORKS) ACT, 1938

An Act to provide for relief from rates in respect of air raid protection works. 29/7/38.

SECTION **1.—Relief of Air Raid Protection Works from Rates**

(1) In rating a hereditament no regard shall be had

(*a*) To any room or other part added solely for air raid protection and *not occupied or used for any other purpose.*

(*b*) Any structural alterations or improvements solely for air raid protection.

(2) No person shall be liable for rates on any premises used *solely* for A.R.P. purposes.

(3) Any room or part of a hereditament as referred to above, having been used for purposes other than air raid protection renders it liable for rates.

SECTION **2.—Citation and Construction**

Appropriate acts on this matter construed as one.

FIRE BRIGADES ACT, 1938

An Act to make further provision for fire services in Great Britain and for purposes connected therewith. 29/7/38.

FIRE AUTHORITIES

SECTION **1.—Provision of Fire Services**

(1) Every county borough and every county district referred to as a " fire authority " shall make provision for the extinction of fires and the protection of life and property by securing—

(*a*) the services of such brigade and fire engines, appliances and equipment as may be necessary ;

(*b*) training of the fire brigade ;

(*c*) arrangements for calling the fire brigade, summoning the members and manning the fire engines ;

(*d*) arrangements for obtaining information of the character of the buildings and other property, available water supplies and means of access thereto,

the services secured under this subsection are referred to as " local fire services."

(2) The Secretary of State may prescribe standards of efficiency according to the requirements and facilities of the locality and any fire authority whose fire services are of a standard so prescribed shall be deemed to have complied with the provisions of the foregoing subsection.

(3) A fire authority may secure local fire services by themselves providing and maintaining such services or by arranging for the provision and maintenance, by other fire authorities or person.

(4) An officer authorised by the authority shall, for carrying out arrangements as are mentioned in paragraph (*d*) (1), have the like powers of entering premises as conferred upon authorised officers of councils by the Public Health Act, 1936.

(5) Every fire authority shall arrange with other fire authorities for assistance by those authorities in dealing with fires occurring in the borough or district which cannot adequately be dealt with by the local fire services. The Secretary of State may prescribe scales of payments to be made, unless otherwise agreed, by the authority receiving the assistance.

(6) A fire authority shall have power—

(*a*) to provide accommodation for any fire brigade, fire engines, appliances or equipment serving their borough or district, including housing and other accommodation for members of any fire brigade and furniture reasonably required;

(*b*) to purchase compulsorily by an order made by the authority and confirmed by the Minister of Health any land required for their functions;

(*c*) to pay to any persons who render services such rewards as they think fit, which in the case of members of a fire brigade may be in addition to their remuneration;

(*d*) to employ a fire brigade maintained by them and any equipment outside their borough or district; and

(*e*) to make payments for fire services provided by another fire authority or other person.

(7) Where a fire authority who are the council of a borough having a separate police force, delegate to the watch committee their functions the watch committee may employ the chief officer of police, and assistant chief constable or the deputy chief constable on administrative duties with a fire brigade maintained by that authority and employ other constables as members of the brigade: From the expiration of a period of five years from the passing of this Act, no such other constables shall be employed as part-time members of a fire brigade.

(8) A fire authority may provide and maintain fire alarms in any street or public place after consultation with the chief officer of police and any fire alarm may be affixed to any wall or fence adjoining a street or public place:

Provided that—

(*a*) a fire authority before exercising its powers in relation to any trunk road shall consult with the Minister of Transport, and, in relation to any county road maintained by a county council, shall consult with the county council and shall not obstruct or render less convenient the access to any station or goods yard belonging to a railway company, or any premises belonging to other statutory undertakers ;

(*b*) nothing in this subsection shall affect any privilege conferred on the Postmaster-General by the Telegraph Act, 1869.

SECTION **2.—Fire-Hydrants and Water Supply in Case of Fire**

(1) Every fire authority shall provide and maintain fire-hydrants necessary for using the available supply of water and the situation indicated.

(2) The provisions of the Waterworks Clauses Act, 1847 (which require undertakers to provide and maintain fire-hydrants) shall have effect as if for the references to the town commissioners there were substituted references to the fire authority.

(3) Where any fire-hydrant which is being maintained at the expense of a fire authority is damaged as the result of any person using the hydrant (otherwise than for fire brigade purposes) with the authority of the water company or person to whom the hydrant belongs, the fire authority shall not be liable for the cost of repairing or replacing the hydrant.

(4) Any person who uses a fire-hydrant, otherwise than for its purpose, or damages or obstructs any fire-hydrant, shall be liable to a fine not exceeding ten pounds.

(5) At least seven days before any fire-hydrant is placed in any street, notice shall be given to the authority and at least seven days before any works affecting any fire-hydrant are commenced, notice shall be given to the fire authority.

(6) A fire authority may enter into agreements with any water company for the provision of an adequate supply of water.

(7) A fire authority may use any supply of water, but shall pay reasonable compensation :

Provided that nothing in this subsection shall affect the duty of undertakers by supplying water for the said purpose without compensation.

(8) Every council who are a fire authority shall take steps to improve the access to any water supply which may be required.

SECTION 3.—**Power of Fire Authority to require Proposed Water Works to be constructed in Manner Specified by them**

(1) Where a person proposes to carry out works for the purpose of supplying water to any part of the borough or district of a fire authority, he shall give notice in writing to the authority and the authority may give notice to that person requiring him to carry out the works in a manner specified by the authority for securing the best supply of water.

If he is aggrieved by the requirements of the authority he may appeal to the Minister of Health.

(2) A fire authority shall repay to the person carrying out the works the extra expenses incurred by him in complying with their requirements and repay to him any expenses incurred in repairing or maintaining the works and if any question arises as to the amount of payment to be made that question shall be determined by an arbitrator appointed by the Minister of Health and the decision of the arbitrator shall be final.

(3) If any person required to carry out works carries them out otherwise than in accordance with the requirements of the authority, he shall be liable to a fine not exceeding fifty pounds and the court may, in addition, order him within the time specified in the order to take steps for remedying the matters, and if he fails to comply with the order he shall be liable to a fine not exceeding five pounds for each day on which the default continues.

SECTION 4.—**Expenses of Rural District Council in connection with Fire-Hydrants and Water Supply**

The expenses of a rural district council under sections two and three of this Act shall be general expenses of the council.

SECTION **5.—No Payments to be made by Owners and Occupiers in respect of Certain Fire Services**

A fire authority shall not require the owners or occupiers of property on which fires occur to make any payment. Provided that this section, so far as it relates to the powers of fire authorities to require payments in respect of the expenses of fire brigades in attending fires outside the borough or district of the authority by whom the brigade is maintained, shall not come into operation until two years from the passing of this Act.

SECTION **6.—Cessation of Functions and Transfer of Property of Parish Authorities**

(1) Six months from the passing of this Act, the functions of parish authorities shall be transferred to the fire authority for the district.

The Secretary of State may by order postpone the operation of this subsection, in relation to any parish to a date as specified in the order.

(2) A fire authority to whom property rights and liabilities are transferred shall, if the value of the property and rights is more than sufficient to defray the liabilities, pay to the parish authority such sum as may be agreed upon or, in default of agreement may be determined by arbitration.

(3) All deeds, bonds and agreements made or entered into by a parish authority for the functions shall have effect from the date of the transference and may be enforced by or against the fire authority; and all proceedings with the substitution of the fire authority as party to the proceedings in lieu of the parish authority.

(4) Any question arising under this section shall be determined by an arbitrator appointed by the Secretary of State, and the decision of the arbitrator shall be final.

SECTION **7.—Provisions for Transfer and Compensation of Employees of Parish Authorities**

On the date when the functions of any parish authority cease to be exercisable, any person who was employed by a parish authority for the purposes of those functions, shall be

employed by the fire authority in whose district the parish is situated on the terms and conditions on which he was so employed immediately before that date, and any of his service in the brigade of the parish authority, which is approved service within the meaning of the Fire Brigade Pensions Act, 1925, shall be reckoned for the purposes of the Act as approved service in the brigade of the fire authority; and the provisions of subsections (2) (3) and (6) of section one hundred and fifty of the Local Government Act, 1933, and of the Fourth Schedule to that Act shall apply to persons transferred to employment by a fire authority under this section as they apply to officers transferred under a scheme or order made under the said section one hundred and fifty, with such adaptions as may be made by an order of the Secretary of State.

Co-ordination of Fire Services

Section 8.—Appointment of Fire Service Commission to Report on Fire Services

(1) A Commission shall be constituted to be called "the Fire Service Commission" for considering the arrangements made for assistance for dealing with fires, and of reviewing the fire services provided by fire authorities and reporting to the Secretary of State on the matters.

(2) The provisions of the First Schedule to this Act shall have effect with respect to the constitution and proceedings of the Fire Service Commission.

(3) The Fire Service Commission may hold such local inquiries as they think fit and subsections (2) and (3) of section two hundred and ninety of the Local Government Act, 1933, shall apply to such inquiries.

Section 9.—Schemes for Co-ordination of Fire Services

(1) If the Fire Service Commission report that adequate arrangements have not been made for assistance they may submit to the Secretary of State a scheme (referred to as a "co-ordination scheme") ensuring the provision of such assistance:

Before submitting any co-ordination scheme, the Commission shall give an opportunity to all fire authorities affected

to make representations and shall submit any such representations together with the scheme.

(2) Payments in respect of assistance provided under the scheme shall be made out of a common fund to which the fire authorities shall contribute in such proportions as may be specified in the scheme, on a scale prescribed by the Secretary of State.

(3) A co-ordination scheme may contain such provisions requiring uniformity of appliances and equipment for the purpose of ensuring that the fire brigades affected will be able to render efficient assistance.

(4) A co-ordination scheme shall come into operation when approved by the Secretary of State and when a scheme has been so approved, it shall be the duty of the fire authorities to carry it into effect and arrangements made under sub-section (5) of section one of this Act which are not in conformity with the scheme shall cease.

(5) If at any time the Fire Service Commission, after consultation with the fire authorities affected, submit to the Secretary of State proposals for amending any co-ordination scheme, the Secretary of State may amend the scheme in accordance with the proposals, subject to any modifications which he may think fit.

SECTION 10.—Power of Fire Service Commission to recommend Provision of Local Fire Services for any District by another Fire Authority

(1) Where any fire authority have requested another fire authority to provide the whole or any part of the local fire services for the borough or district of the first named fire authority, and the other fire authority are unwilling to provide such services, or the authorities cannot agree as to the extent of the services to be provided or the terms on which they are to be provided, the first named fire authority may make an application to the Fire Service Commission.

(2) If the Fire Service Commission, after holding a local inquiry, are satisfied that it is securing greater efficiency and economy, if the whole or any part of the local fire services for the borough or district of the applicant fire authority be provided, they may recommend to the Secretary of State that such local

fire services shall be so provided and the Secretary of State may give effect to the recommendations and thereupon it shall be the duty of the fire authorities concerned to give effect to the order.

(3) The costs in holding a local inquiry shall be paid by such fire authorities as the Commission may direct, and the Commission may certify the amount of the said costs.

SECTION **11.—Fire Service Boards**

(1) If the Secretary of State is satisfied after two years from the passing of this Act that efficient fire services have not been provided he may appoint a board to be called " a fire service board."

(2) The Second Schedule to this Act deals with fire service boards.

(3) From the date of the appointment of a fire service board, no arrangements shall be entered into by the fire authorities situated in the area for which the board was appointed without the approval of the fire service board.

SECTION **12.—Fire Service Area Schemes**

(1) Where a fire service board has been appointed it shall prepare and submit to the Secretary of State a scheme (referred to as " an area scheme ") for ensuring the provision and maintenance of efficient fire services throughout the area.

(2) An area scheme shall come into operation when approved by the Secretary of State, and when a scheme has been so approved, the fire authorities must carry it into effect and any arrangements not in conformity with the scheme shall cease to have effect.

(3) If at any time the fire service board after consultation with the fire authorities submit to the Secretary of State proposals for amending the scheme, the Secretary of State may approve the scheme subject to any modifications which he may think fit.

SECTION **13.—Default Powers of Fire Service Boards**

(1) If a complaint is made to the Secretary of State by a fire service board that any fire authority have failed to carry out the area scheme, the Secretary of State may, after a local

enquiry, transfer the functions to the fire service board, and while the order is in force the fire service board shall discharge those functions in place of the authority.

(2) A fire service board to whom functions are transferred may borrow money for the purpose of meeting any expenses incurred and Part IX of the Local Government Act, 1933, shall apply, subject to such adaptations as may be made by the order transferring the functions.

(3) A fire service board can order any fire authority whose functions have been transferred to the board to pay such amounts as will be sufficient to defray expenses incurred ; and any sum for which a precept has been issued shall be a debt due to the fire service board.

(4) Where functions have been transferred, the accounts of the board shall be so kept as to show in a separate account such income and expenses as are attributable to the exercise of functions so transferred.

(5) Where an order transferring functions is revoked, the functions shall again be exercisable by the authority from whom they were transferred and the revoking order may provide for the transference to that authority, of any property rights and liabilities acquired or incurred by the board for the purpose of the exercise of those functions.

Miscellaneous

Section 14.—**Powers of Fire Brigades and Police in Extinguishing Fires**

(1) Any member of a fire brigade and any police constable may enter and if necessary break into any premises or place in which a fire has or is reasonably supposed to have broken out, without the consent of the owner.

(2) Any person who wilfully obstructs or interferes with any member of a fire brigade engaged in extinguishing a fire shall be liable to a fine not exceeding ten pounds.

(3) At any fire the senior officer present of the fire brigade or any other person in charge of the operations for the extinction of the fire shall have the sole charge and control of all operations and may require the water to be shut off in order to give a greater supply and pressure, and no authority,

company or person shall be liable to any penalty or claim by reason of the interruption of the supply of water.

(4) The senior officer of police present at any fire may close for traffic any street or may stop or regulate the traffic in any street whenever it is necessary to do so.

SECTION **15.—Power to Exempt Trailers used for Fire Services from Traffic Restrictions**

The Minister of Transport may exempt from the section of the Road Traffic Act, 1930, (which restricts the number of trailers to be drawn by motor vehicles) ; vehicles used for fire brigade purposes.

SECTION **16.—Extension of Fire Brigade Pensions Act, 1925, to Temporary Firemen**

(1) Where any member of a fire brigade maintained by a fire authority who has been a professional fireman or member of a police force, is wholly but not permanently employed on fire brigade duties, and while so employed is incapacitated for the performance of his duty he shall receive a pension to himself or to his widow and allowances to his children or dependants payable under the Fire Brigade Pensions Act, 1925, as would have been payable if he had been a professional fireman when incapacitated, but based on his current rate of pay and his service with the brigade since he last joined it.

(2) Where any special pension is payable to a person to whom an ordinary pension is already payable, the special pension shall be in addition to his ordinary pension, but no increase made in respect of service and the aggregate amount of the two pensions shall not exceed his annual pay at the date of his retirement.

(3) Where pensions, allowances, or gratuities are payable under any local Act to members of a fire brigade the Secretary of State may direct that the provisions of this section shall apply with respect to that fire brigade with such modifications as he considers necessary.

SECTION **17.—Definition of " Fire Brigade Duties " for purposes of Fire Brigade Pensions Act, 1925**

For the purposes of the Fire Brigade Pensions Act, 1925,

and this Act, the expression "fire brigade duties" includes any of the following duties; that is to say:—

(*a*) duties carried out on the direction of the fire authority in connection with fire prevention;

(*b*) duties in connection with the construction, repair or maintenance of any fire engines, or of any vehicles, appliances or equipment used for fire brigade ambulance or police purposes, or duties consisting of the driving or manning of ambulances; and

(*c*) other duties ancillary to or connected with fire brigade purposes.

SECTION 18.—Central Advisory Council for Fire Services

(1) The Secretary of State shall appoint a Council called the Central Advisory Council for Fire Services; and

(2) May make provision with respect to the constitution and proceedings of the Council.

SECTION 19.—Appointment of Inspectors

The Secretary of State may appoint paid inspectors for the purpose of this Act.

SECTION 20.—Establishment of Training Centre

The Secretary of State may establish a training centre for fire brigades and the expenses incurred defrayed under this Act.

SECTION 21.—Loan to Fire Authorities of Appliances provided under the Air Raid Precautions Act, 1937

Regulations made by the Secretary of State under the Air Raid Precautions Act, 1937, may provide for the use by fire authorities of any equipment, appliances or material acquired under the said Air Raid Precautions Act, 1937.

SECTION 22.—Power of Secretary of State to require Uniformity

The Secretary of State may impose requirements as to uniformity of appliances, equipment and fire hydrants for securing efficient services and rendering efficient mutual assistance.

SUPPLEMENTARY

SECTION **23.—Notices**

Any notice required or authorised by this Act to be given to any person may be given either :—

(*a*) by delivering it to that person, leaving it or sending in a prepaid letter addressed to him at his usual or last known residence ; or

(*b*) in the case of an incorporated company or body by delivering it to their secretary or clerk at their registered or principal office, or by sending it in a prepaid letter addressed to him at that office.

SECTION **24.—Provisions as to Orders of Secretary of State**

(1) Any order made by the Secretary of State may be varied or revoked.

(2) The Secretary of State shall consult the Central Advisory Council for Fire Services and with associations representing fire authorities before making any order as regards standard of efficiency and uniformity.

(3) Any order made by the Secretary of State prescribing standards of efficiency and uniformity shall be laid as soon as may be before Parliament, and if either House resolves that the order be annulled, the order shall be of no effect.

SECTION **25.—Power of Secretary of State to hold Inquiries**

The Secretary of State may hold a local inquiry into the manner in which any fire authority are performing their functions under this Act.

SECTION **26.—Expenses of the Secretary of State, Fire Service Commission, Fire Service Boards and Central Advisory Council**

All expenses of the Secretary of State incurred for the purposes of this Act shall be defrayed out of moneys provided by Parliament.

SECTION **27.—Provisions as to London**

(1) The provisions of subsections (3) to (7) of section two and the provisions of sections three, five, fifteen and twenty-one

of this Act shall apply to the administrative county of London and the London County Council and accordingly—

(*a*) the references to a fire authority borough or district shall be construed as including references to the London County Council and the administrative county of London, respectively:

(*b*) the reference in section twenty-one to this Act shall include reference to the Metropolitan Fire Brigade Act, 1865.

(2) The provisions of section one of this Act shall have effect so as to enable such fire services to be provided by the London County Council and the references in subsections (3) and (5) of section one to other fire authorities and the references in subsection (4) thereof to a fire authority shall be construed as including references to the London County Council; and the duty of a fire authority under subsection (5) of section one of this Act may be discharged by entering into arrangements with the London County Council under section forty-nine of the London County Council (General Powers) Act, 1936.

(3) The London County Council shall have power to purchase compulsorily any land required for the purposes of their functions under the Metropolitan Fire Brigade Act, 1865, and the Local Government Act, 1933.

(4) The power of the London County Council under the Metropolitan Fire Brigade Act, 1865, to permit any part of their fire brigade establishment to be employed on special services shall include a power to permit such employment without requiring any remuneration from the persons to whom the services are rendered.

(5) Save as is in this section provided, this Act shall not apply to the administrative county of London or to the London County Council.

SECTION 28.—Application to Scotland

The provisions of this section shall have effect for the purpose of the application of this Act to Scotland.

SECTION 29.—Interpretation

SECTION 30.—Short Title, Extent and Repeals

CIVIL DEFENCE ACT, 1939

An Act to make further provision for civil defence and for purposes connected therewith. 13/7/39.

DIGEST

PART I

THE MINISTER

SECTION **1.—Transfer of Functions of the Secretary of State**

Enables functions under A.R.P. Act, 1937, and this Act to be distributed among the Government Departments.

PART II

PUBLIC SHELTERS, ETC.

SECTION **2.—Designation of Premises**

(1) Where it appears to the local authority that the whole or any part of a building is or can be made suitable

(*a*) for use as a public shelter;

(*b*) for use in carrying out any of their civil defence functions;

the local authority may post in the building or part a notice declaring that that building or part may be required for use for public purposes of civil defence.

(2) Where the authority post a notice they shall notify the Minister and take steps to bring the contents of the notice to the knowledge of the persons having estates or interests in the building, and the notice shall be registered as a local land charge.

(3) The local authority may withdraw any such notice by posting a notice to that effect in the building.

(4) A building where a notice under subsection (1) has been posted and has not been withdrawn is in this Act referred to as "designated premises."

(5) The local authority shall not, without the consent of the appropriate department, designate any premises which either—

(*a*) are occupied by any public utility undertakers;

(*b*) are situate on land over which any public utility undertakers exercise any control.

(6) Where the occupier of any designated premises holds any part of the premises on lease, he shall, immediately he becomes aware of the designation of the premises, serve upon his immediate landlord notice that the premises have been designated.

SECTION 3.—**Appeal from Designation of Premises**

(1) Within fourteen days from the designation any person having any estate or interest therein may appeal to the Minister against the designation on the ground—

(*a*) that the whole or any part of the premises is required for purposes of public importance ; or

(*b*) that the whole or any part of the premises is required for use as a private air raid shelter for the persons in the premises.

SECTION 4.—**Execution of Works**

Where it appears to the local authority expedient for the purpose of making designated premises suitable, they may themselves execute those works :

Provided that—

(*a*) the local authority shall not begin any such works until the period has expired for appealing ;

(*b*) before entering on any premises, the local authority shall give to the occupier at least fourteen days' notice.

SECTION 5.—**Designated Premises to Remain Unaltered**

(1) No person shall, without the consent of the local authority—

(*a*) make any structural alteration in any designated premises ; or

(*b*) remove or alter any works executed by the local authority :

Provided that, if the authority refuse their consent, the applicant may appeal to a court of quarter sessions.

(2) Any person who contravenes the provisions of the preceding subsection shall be liable to a fine not exceeding fifty pounds.

(3) Where the court is satisfied that the contravention has rendered the premises unsuitable, it may order the local authority to charge to the person convicted their reasonable expenses of again rendering the premises suitable.

SECTION **6.—Compensation where Works are Executed**

(1) Where works are executed under the preceding provisions by a local authority, the occupier shall be entitled to recover from the local authority compensation for any damage or any interference with his use of the premises.

(2) Where by the execution of any works the usefulness of any premises is impaired, the local authority shall pay to the occupier periodical sums, payable quarterly in arrear, calculated by reference to the diminution of the annual value of the premises, ascribable to the impairment.

(3) Where the designated premises cease to be such, the payments shall cease, but it shall be the duty of the local authority—

(*a*) to restore the premises; and

(*b*) if, after restoration, the premises are less in value, to pay compensation.

(4) Where a local authority restore any premises, the occupier shall be entitled to recover compensation for any damage.

SECTION **7.—Powers of Local Authorities to Construct Underground Shelters and other Premises required for Civil Defence Purposes**

(1) The local authority may enter on any land, after giving twenty-eight days' notice, and there construct—

(*a*) an underground shelter or premises;

(*b*) entrances to, and shafts for ventilating, draining, lighting and heating.

(2) Where the authority propose to construct underground premises in any protected square, allotment, common or open space, or in any land held by the National Trust,

(*a*) the authority shall, in addition to giving notice publish in a newspaper a notice describing their proposals and naming where plans may be inspected free;

(*b*) if, within twenty-eight days, any notice of objection is

served on the local authority, the authority shall refer to the Minister and shall not proceed unless the Minister has approved, either with or without modification.

(3) The local authority may construct a shelter under any highway:

Provided that the consent of the highway authority be obtained.

(4) Any shelter or premises constructed by the local authority shall vest in the authority, and the authority shall have powers of entry.

(5) The local authority shall pay to any person having an estate or interest in any land in which works are constructed, compensation in respect of any damage caused.

(6) The powers conferred on local authorities by this section shall not be exercisable with respect to any land occupied by public utility undertakers.

SECTION 8.—Powers of Local Authorities to Construct Underground Car Parks suitable for use as Air Raid Shelters

(1) (2) A local authority who have power to provide parking places suitable also for use as air raid shelters, exercise the like powers as are exercisable under the last preceding section:

Provided that the local authority shall have regard to the amenities of any unprotected square or land held by the National Trust.

(3) (4) Where the local authority shall

(*a*) give notice to the Minister and the Minister of Transport;

(*b*) publish by advertisement the nature of their proposals.

(5) (6) The local authority shall not proceed with any proposals, unless the Minister has approved the proposals.

(7) So much of the expenses attributable to the rendering of the parking place suitable as a shelter shall be deemed expenditure under the Act of 1937.

SECTION 9.—Power of Local Authorities to Construct Air Raid Shelters in Streets

(1) The local authority may provide a public shelter on any highway.

(2) The local authority shall not exercise their power under this section without the consent of the highway authority.

(3) The local authority shall—

(*a*) serve upon the occupiers of any land or building adjoining the site a notice stating their intention and the general nature of the shelter.

(*b*) affix a similar notice upon the site.

(*c*) cause a similar notice to be published.

(4) The local authority shall not interfere with any mains, pipes, apparatus or works belonging to public utility undertakers unless they have given fourteen days' notice; and if the local authority cause any damage, they shall repay to the undertakers the expenses incurred by them in making good.

(5) The authority shall pay to any persons having an estate or interest in any land or building adjoining the highway on which a shelter is constructed such compensation, if any, as may be just in respect of any depreciation of their property.

Section 10.—Agreements under Part II between Local Authority and Occupiers of Factory Premises and Owners of Commercial Buildings

(1) The local authority may, if air raid shelter cannot be provided in factory premises, agree with the occupier to provide on payment by the occupier to the local authority, a public air raid shelter for use, in whole, or in part.

(2) Subsection (1) of this section shall apply in relation to commercial buildings.

Section 11.—Local Authorities for Purposes of Part II

This section defines "Local Authorities" for the purpose of Part II.

Part III

Private Shelters and Training in Certain Factories, Mines and Buildings

Section 12.—Application of Part III

This Part of this Act, except the provisions relating to the training of employed persons, shall apply only to areas specified

in an order made by the Minister, and references to factory premises, mines and commercial buildings shall be construed as references to factory premises, mines and commercial buildings which are situate in such an area.

The Minister may by order declare that any specified factory premises, mine or commercial building shall be treated as if the premises were included in such an area as aforesaid.

SECTION **13.—Code for Occupiers of Factories, etc.**

(1) For the guidance of occupiers and owners and other persons concerned, in providing air raid shelter, the Minister shall issue a code prescribing requirements with which the shelter must comply.

(2) In this Act the expression "shelter of the approved standard" means air raid shelter which at least complies with all the requirements prescribed by the code.

SECTION **14.—Duty of Occupiers of Factory Premises and Owners of Mines and Commercial Buildings to make Reports**

(1) It shall be the duty of occupiers of any factory premises, owner of any mine or owner of any commercial building—

(*a*) not later than three months from the appropriate date to report in the case of factory premises to the factory inspector for the district, in the case of a mine to the mines inspector for the district, and in the case of a commercial building, to the local authority, stating what measures he has taken or is taking or proposing to take to provide air raid shelter for the persons working or living in the factory premises, working in or about the mine, or working or living in the commercial building.

(*b*) on the completion of any works not begun or still incomplete at the date of the report, to report their completion.

(2) If any person fails to report he shall be liable to a fine not exceeding one hundred pounds and ten pounds for each day on which the failure continues.

(3) "The appropriate date," whichever of the three following is the latest—

(*a*) the first issue or approval of a code ;

(*b*) the making of an order applying this part of this Act to, or to an area containing, the premises, mine or building.

(See Section 89)

SECTION **15.—Power of Occupier or Owner to Execute Works**

The occupier of any factory premises, the owner of any mine and the owner of any commercial building may execute any works for providing shelter of the approved standard.

SECTION **16.—Power of Factory Inspector, Mines Inspector or Local Authority to require Provision of Air Raid Shelter**

(1) A factory inspector may serve on the occupier of factory premises, a mines inspector may serve on the owner of a mine, and the local authority may serve on the owner of a commercial building a notice requiring him to provide air raid shelter of the approved standard for all or any of the persons working or living in the factory premises, working in or about the mine, or working or living in the commercial building.

(2) Any such notice shall specify the nature and the situation of the shelter, and the number of persons to be accommodated.

(3) Such notices shall also state—

(*a*) the shelter is to be provided within such time as specified ;

(*b*) that time will begin to run twenty-eight days after the service of the notice.

(4) An occupier or owner on whom such a notice has been served shall not execute works except for the purpose of complying with the said requirements.

(5) If any person fails to comply with a notice he shall be liable to a fine not exceeding one hundred pounds and to a fine not exceeding fifty pounds for each day on which the default continues.

(6) Where a notice is served on the occupier who is not the owner, he shall, within fourteen days, serve a copy on his immediate landlord.

(7) Where a notice is served on the owner of a commercial building who is not the occupier of the whole building, he shall serve a copy thereof on

(*a*) every lessee ; and

(*b*) the occupier.

(8) Where a notice is served on the occupier of factory

premises or the owner of a commercial building and the occupier or owner holds any part of the premises or building on lease, he shall within fourteen days serve a copy upon his immediate landlord.

(9) A notice under this section requiring the provision of air raid shelter shall be deemed to be complied with if, by an agreement under Part II of this Act between the occupier and the local authority, shelter is provided in a public shelter.

Note. It is the duty of the owner to provide the design for the shelter.

SECTION **17.—Appeals**

(1) Any person who is liable to an increase of rent in respect of the expenses of the owner of the building in providing the said shelter, may appeal to the Minister on the ground that—

(*a*) the proposals or requirements of the notice are not appropriate;

(*b*) it is not reasonable to require the provision of any air raid shelter in the case of the premises, mine, or building.

Subsections (2), (3) and (4) deal with legal proceedings and time limits.

SECTION **18.—Provisions as to Factory Premises occupied under Short Leases**

Legal arrangements only.

SECTION **19.—Provision as to Commercial Buildings when Owner does not Occupy the Whole Building**

(1) Where works are executed by the owner of a commercial building in any part thereof of which he is not the occupier, the occupier of that part of the building shall be entitled to recover from the owner compensation for any damage.

(2) Where the usefulness of any part of a commercial building is impaired in connection with, or after, the provision of the shelter, the rent shall be decreased to the extent and for the period specified in the subsequent provisions of this section.

(3) The said decrease shall be at an annual rate equal to the diminution of the annual value ascribable to the impairment.

(4) Where the owner of a commercial building who is not the occupier of the whole building, has incurred expenses in providing shelter, then the rent shall be increased to the extent and for the period specified in the subsequent provisions of this section.

(5) The said increase shall be at the annual rate of the total of the two following amounts—

(*a*) one-tenth of the expenses of the owner under the notice ;

(*b*) any diminution of the annual value of any part of the building ascribable to an impairment.

(6) The said increase shall operate in relation to a lease, notwithstanding that the rent payable thereunder is decreased under the provisions of subsection (2).

(7) No increase or decrease shall operate more than ten years.

(8) In this section the expression " expenses " in relation to a notice means the expenses reasonably incurred by the owner in providing shelter of the approved standard, together with—

(*a*) any compensation ;

(*b*) where the owner is the occupier of any part of the building compensation which he would have been entitled to recover from the owner if he himself had not been the owner.

Where shelter provides a greater degree of protection than is contemplated by the code, no greater expense shall be deemed to have been reasonably incurred than would have been incurred if that greater degree of protection or accommodation had not been provided.

(9) If any lessee proves that he was not a person on whom the notice was required to be served such reduction shall be made in the amount of the increase of rent payable under his lease as may be just.

(10) A surety for the payment of any rent which is increased under this section shall not be discharged by reason of the increase, but shall not be liable in respect of the increase.

(11) Where an owner claims an increase of rent under this section he shall not be entitled to claim those expenses or any part thereof under any term of a lease requiring the tenant to pay outgoings.

(12) Subsections (4), (5), (7), (10) and (11) of this section shall apply in relation to any sums for which the owner of a commercial building becomes liable to a local authority under an agreement for the provision of a public air raid shelter for the use, in whole or in part, of persons working or living in the building.

SECTION **20.—Contributions in respect of Works commenced before the Passing of the Act**

(1) Where any person has, before the passing of this Act, commenced works for air raid shelter of the approved standard he may make a claim to the tribunal for the payment of contributions towards the expenses incurred in providing the shelter.

(2) The persons liable to make contributions are persons having an estate or a leasehold interest in the premises.

(3) The tribunal

(*a*) may set aside or vary the terms of any agreement;

(*b*) may order that the contributions take the form of increases or decreases of rent, or a lump sum or periodical payments.

(4) In this section, references to the expenses incurred by any person in providing air raid shelter shall include—

(*a*) any sum to pay as compensation;

(*b*) if the works are executed in a part of the premises occupied by him, the impairment of its value.

SECTION **21.—Saving for Rights of Occupier or Owner existing apart from this Part**

Nothing shall be construed as preventing the occupier of any factory premises, the owner of any mine or the owner of a commercial building from doing anything with a view to providing air raid shelter, unless the doing thereof is inconsistent with a notice duly served on him.

SECTION **22.—Exchequer Grants in respect of Provision of Air Raid Shelter in Factory Premises, Mines, Commercial Buildings, etc.**

(1) There shall be paid out of moneys provided by Parliament to every occupier of factory premises and to every owner

of a mine or commercial building who provides air raid shelter of the approved standard, a grant equal to the appropriate proportion of so much of the expenses of a capital nature incurred by him as the Minister considers reasonable.

(2) There shall be paid out of moneys provided by Parliament to every person who incurs expenses of a capital nature in providing air raid shelter of the approved standard for persons employed by him, a grant equal to the appropriate proportion of so much of those expenses as the Minister considers reasonable.

Provided that nothing in this subsection shall apply to any public utility undertakers.

(3) The expression " the appropriate proportion " means an amount in the pound equal to the standard rate of income-tax for the year 1939–40.

(4) No grant shall be paid unless either—

(*a*) the shelter has been provided before the end of September nineteen hundred and thirty-nine ; or

(*b*) work on the shelter is then in progress, or preparatory measures are then being taken for the provision of the shelter and (in each case) the Minister is satisfied that the shelter will be provided within a reasonable time thereafter ;

And no expenses shall be deemed reasonable in so far as they exceed such standard as may be prescribed.

(5) This section applies in relation to a shelter provided before, as well as in relation to a shelter provided after, the passing of the Act.

SECTION **23.—Training of Employees**

(1) This section applies to every person who employs more than thirty persons.

(2) It shall be the duty of every person to whom this section applies, not later than one month from the date on which this section first applies to him, to report stating what measures he has taken or is taking or proposes to take to secure that all the persons employed by him are trained as respects the routine to be followed in the event of an air raid, and that a suitable proportion of those persons are trained and equipped

to give first aid treatment, to deal with the effects of gas and to fight fires.

(3) A factory inspector, a mines inspector and a local authority may serve on an employer a notice requiring him to take such measures in relation to the aforesaid matters.

(4) Any person may, within fourteen days after receipt of the notice, appeal to the Minister, and the decision of the Minister shall be final.

(5) Any person failing to report or to comply with a notice, shall be liable to a fine not exceeding one hundred pounds, and to a fine not exceeding fifty pounds for each day on which the default so continues.

Section 24.—Saving for Certain Authorities

This Part shall not require the making of reports by, or authorise the service of any notice, or any local authority or any police authority.

Section 25.—Local Authority for Purposes of Part III

"Local authority" means the council of a county borough or county district, and in the last any local authority within the meaning of the Act of 1937. See section 35 for L.C.C. areas.

Part IV

Other Provisions as to Shelter

Section 26.—Erection of Shelters provided by the Crown

(1) Where the occupier has been provided with materials for an air raid shelter the local authority shall give him advice as to the position in which the shelter should be erected.

Provided that, where the materials are sold to the occupier, the authority shall not be under any duty to give advice until requested.

(2) Any occupier to whom advice has been given may erect the shelter and may break up the surface of any land in his occupation whether paved or not, but shall take care not to damage any drains, sewers, pipes, cables or other works; notwithstanding any agreement or restrictive covenant to pay damages, if he has exercised due care.

(3) The local authority shall in giving advice exercise care, but unless they fail to exercise such care, they shall not be liable for damage caused by erection in accordance with advice given by them.

(4) Where any materials for shelter have been provided without charge, the local authority may, with the consent of the occupier, themselves erect the shelter.

(5) References to the erection of an air raid shelter include references to the affixing to, or the embedding of the shelter, in any part of the premises.

(6) Public utility undertakers shall not, unless they have been guilty of negligence, be liable to pay damages for or in respect of any loss of life or injury or damage to persons or property resulting from damage done by any occupier to any pipe, cable, or other work in the exercise of the powers conferred by subsection (2) of this section; provided that nothing in this subsection shall be in derogation of any provision in the Workmen's Compensation Act, 1925.

(7) This section shall be deemed to have had effect as from the commencement of the Act of 1937.

SECTION 27.—Affixing of Appliances provided by the Crown for Strengthening Basements

(1) Where the occupier of any basement has been provided free with appliances for strengthening, it shall be the duty of the local authority—

(*a*) to affix these appliances, and

(*b*) to take such steps as appear desirable in order to provide additional exits; and

they shall have power to execute such works; and shall not be liable to pay damages except in respect of damage to any mains, pipes, apparatus or works belonging to public utility undertakers.

(2) This section shall be deemed to have had effect as from the commencement of the Act of 1937.

SECTION 28.—Restriction of Removal of Shelters and Appliances

(1) Any materials for an air raid shelter provided free shall not be removed from the premises without the consent of the local authority.

(2) and (3) Any shelter erected or appliances affixed by the local authority shall not be removed from its position without the consent of the local authority, given absolutely or subject to conditions.

(4) Any person who removes any shelter, materials or appliances in contravention of this section, shall be liable to a fine not exceeding twenty pounds.

SECTION **29.—Loans by Local Authorities to Owners of Dwelling-Houses**

(1) The local authority may advance money to the owner of any premises comprising a dwelling-house in an area specified by the Minister for the purpose of enabling the owner to provide an air raid shelter of a permanent character.

(2) Every such advance shall be repaid with interest within ten years from the date of the advance, and the rate of interest as may be agreed, not being less than one-quarter per cent. in excess of the rate fixed in respect of loans to local authorities for the purposes of Part V of the Housing Act, 1936.

(3) Any amount due by way of repayment shall be a charge on the premises and the local authority shall have the same remedies under the Law of Property Act, 1925.

(4) The Public Works Loans Commissioners may make loans to any local authority for the purpose of advances under this section.

(5) In this section the expression "owner" means the person in whom the fee simple is vested, and includes also a lessee under a lease the unexpired term of which exceeds three years.

SECTION **30.—Provision of an Air Raid Shelter in Certain Buildings**

(1) The owner of any block of buildings may prepare a scheme for providing shelter in or near the building for the persons living and working in the building or block.

(2) In this section the expression "building or block of buildings" means a building wholly or mainly used for residential purposes :

Provided that—

(*a*) so much of any building as consists of any factory premises or commercial building shall be disregarded ;

(*b*) the said expression does not include any building owned by any local authority ;

(*c*) the said expression does not include a building in the case of which the majority of the occupiers are entitled to a free issue of materials for a shelter.

(3) Any such scheme shall—

(*a*) state the situation and the general nature of the shelter and the number of persons which the shelter is to accommodate ;

(*b*) state the estimated cost exclusive of compensation ;

(*c*) state what compensation is proposed to be paid by the owner or proposed to be allowed to the owner ;

(*d*) contain a statement of the effect as to increases of rent.

(4) The owner shall serve a copy of any such scheme on the occupier of every separate part of the building.

(5) Unless the occupiers of more than one-half in number of the separate parts of the building or block dissent from the scheme, the owner shall carry the scheme into effect and the rent payable under every lease derived from the estate shall be increased to the extent subsequently provided in this section.

(6) The increase shall be calculated as follows :—

(*a*) there shall first be taken the expenses of the owner in providing the shelter (exclusive of compensation) ;

(*b*) there shall then be added

(i) the amount, if any, to be paid by the owner as compensation ; and

(ii) the amount to be allowed as compensation to the owner ;

(*c*) there shall then be ascertained the proportion which the annual value of the part of the building to which the lease in question relates bears to the annual value of the whole building ;

(*d*) the proportion so arrived at shall be applied to the sum ascertained under paragraphs (*a*) and (*b*) of this sub-section ; and

(*e*) the increase in rent shall be at the annual rate of one-eighth of the sum arrived at under paragraph (*d*).

(7) The rent on which the said increase operates is all rent payable under the lease after the date of the completion of the shelter: no increase shall operate for more than ten years.

(8) A surety for the payment of rent increased shall not be discharged by reason of the increase, but shall not be liable in respect of the increase.

(9) Nothing in this section shall be construed as authorising the owner to enter upon any premises if he would not have been entitled to apart from the provisions of this section.

(10) In this section—

(*a*) the expression "owner" has the same meaning as that expression has in relation to a commercial building; and

(*b*) the expression "separate" means a part which is in separate occupation;

(*c*) the expression "rent period" means, in relation to a lease, the quarter or other period in which an instalment of rent becomes payable;

and where a part is occupied under a lease of which the unexpired term is less than six months, that person shall be deemed the occupier who would be the occupier if every such lease had been surrendered.

SECTION **31.—Special Provisions as to Land used in Common by Tenants of Certain Buildings**

(1) If, in the case of any block of buildings, there is adjacent land used in common by the occupiers, a request signed by more than one-half of the occupiers, that the local authority should utilise that land for the construction of a shelter shall confer upon the local authority rights of entry upon the land.

(2) In this section the expression "building or block of buildings" means a building which is situated in an area specified by the Minister, is mainly used for residential purposes and is let out in separate parts:

Provided that—

(*a*) so much of any building as consists of any factory or commercial building shall be disregarded;

(*b*) the said expression does not include any building the owner of which may be required to provide shelter under the last section.

SECTION **32.—Execution of Works by Owner of Dwelling-house**

(1) The owner of any dwelling-house may provide shelter in the house or on land belonging to or occupied with the house, notwithstanding any agreement or restricted covenant to the contrary.

(2) In this section the expression "owner" means the person in whom the fee simple is vested, and includes also a lessee under a lease, the unexpired term of which exceeds three years.

SECTION **33.—Power to make Regulations as Construction, Alteration or Extension of Buildings**

(1) The Minister may make regulations, imposing

(*a*) such requirements as to materials and construction as he considers necessary for rendering the buildings less vulnerable to air raids;

(*b*) such requirements as to provision of shelter for the persons using or resorting to the buildings.

(2) Regulations shall apply to buildings erected after the date of the regulations, and to buildings in which structural alterations are made, or which are extended, after that date.

(3) Regulations may apply generally or different requirements may be prescribed for different areas and different classes of buildings.

(4) It shall be the duty of the local authority to enforce regulations made under this section.

Subsections (*a*), (*b*), (*c*) and (*d*) deal with legal points and fines for offences.

(5) Where the local authority consider that the operation of any regulation would be unreasonable in relation to any particular case, they may with the consent of the Minister, relax the requirements of the regulation or dispense with compliance therewith.

(6) Any building byelaws which are inconsistent with regulations made under this section shall be void to the extent of the inconsistency.

(7) In this section the expression "building byelaws" has the meaning assigned to it by the Public Health Act, 1936.

(8) In relation to any electricity generating station the references to the Minister are references to the Electricity Commissioners, acting with the concurrence of the Minister.

SECTION 34.—Increase of Housing Subsidy as respects Certain Flats

(1) In the case of flats, the annual contributions shall be increased by two pounds in respect of each flat and the annual contribution payable by the local authority increased accordingly.

(2) This section applies to blocks of flats, in which air raid shelter

(*a*) is provided to comply with regulations made under the last section; or

(*b*) is provided with the approval of the Minister of Health.

SECTION 35.—Provisions as to Local Authorities for Purposes of Part IV

(1) The expression "local authority" means the council of a county borough or county district.

(2) The council of any county may reimburse to the council of any county district within that county the whole or any part of any expenses incurred by them under the first three sections of this Part of this Act.

PART V

PUBLIC UTILITY UNDERTAKINGS

SECTION 36.—Duty of Public Utility Undertakers to make Reports

(1) All public utility undertakers not later than one month from the passing of this Act must make a report to the appropriate department stating what measures they are taking to secure that all persons employed by them are trained as respects the routine to be followed in the event of an air raid and that a suitable proportion of persons are trained and equipped to

give first aid treatment to deal with the effects of gas and to fight fires.

(2) The appropriate department may serve a notice on any public utility undertakers requiring them to make, in addition to the report required either or both of the following reports :—

(*a*) a report stating what measures they have taken or are taking to provide air raid shelter for the persons employed by them ; and

(*b*) a report stating what measures they are taking to secure the due functioning of their undertaking. It shall be the duty of any undertakers who employ persons within an area specified by the Minister in an order made under Part III of this Act to make a report not later than three months from the making of that order stating what measures they are taking to provide shelter for those persons.

(3) If any undertakers fail to make a report they shall be liable to a fine not exceeding one hundred pounds and to a fine not exceeding ten pounds for each day on which the failure so continues.

SECTION 37.—Power to require Measures to be Taken

(1) The appropriate department may serve on any public utility undertakers a notice requiring them to take such measures as may be specified in the notice.

(2) If any undertakers fail to comply they shall be liable to a fine not exceeding one hundred pounds and to a fine not exceeding fifty pounds for each day on which the failure so continues :

When the court fix a period from the date of conviction for compliance by the undertakers with the requirements the daily penalty shall not be recoverable in respect of any day before the expiration.

SECTION 38.—General Grant in respect of Expenses in Providing Shelter for Employees

(1) Where any public utility undertakers who have made, or are under an obligation to make report or have been served

with a notice requiring them to take such measures have incurred expenses of a capital nature in taking measures for that purpose they shall be paid out of moneys provided by Parliament equal to the appropriate proportion of so much of those expenses as is reasonable.

Provided that—

(*a*) no grant shall be payable unless either the shelter has been provided before the end of September nineteen hundred and thirty-nine or work on the shelter is then in progress or preparatory measures are then being taken and that the shelter will be provided within reasonable time.

(*b*) no expenses shall be deemed to be reasonable if they exceed the standard prescribed by regulations of the Minister.

(2) In this section the expression " the appropriate proportion " means an amount in the pound equal to the standard rate of income tax for the year 1939–40.

SECTION **39.—Grants in respect of Measures to Secure Due Functioning of Undertakings**

(1) There may be paid out of moneys provided by Parliament expenses of public utility undertakers in taking measures to secure the due functioning of their undertakings, grants not exceeding one-half of those expenses.

(2) The expression " approved expenses " means such expenses of a capital nature as the appropriate department may approve.

(3) This section shall not apply in relation to any railway undertaking or electricity undertaking and in relation to any dock or harbour undertaking shall have effect subject to the special provisions of this part of this Act as to those undertakings.

SECTION **40.—Provisions as to Railway Undertakings**

(1) The following provisions shall have effect in relation to any railway undertaking.

(2) The undertakers may be required to make a report stating what measures they have taken or are taking or proposing to take as respects

(*a*) the execution of works or the provision of accommodation, plant, materials or equipment (including stocks of stores) with a view to providing or maintaining essential railway services in the event of hostile attack.

(*b*) the provision for persons employed of such special protection or equipment as may be necessary.

(3) There may be paid by Parliament grants not exceeding such expenses as the appropriate department may approve.

(4) If, in the event of war, control of any such undertaking is assumed by His Majesty's Government on terms as to compensation under which a net revenue in respect of any control accounting period which exceeds such amount determined to represent the corresponding net revenue in respect of a like accounting period before the outbreak of war, the undertakers shall pay to the appropriate department an amount equal to the excess so that the total shall not exceed—

(*a*) one-half of the total grants made under the last preceding subsection ; or

(*b*) the amount by which the sum of the net revenues accruing to the undertakers throughout the control accounting periods, exceeds the sum of the corresponding net revenues of the undertakers in respect of the like accounting periods before the outbreak of war.

The expression "control accounting period" means any financial year throughout which such control exists.

SECTION **41.—Provisions as to Dock and Harbour Undertakings**

(1) If the appropriate department so order the preceding provisions of this part of this Act shall apply in relation to the undertakers carrying on the undertaking as if all persons likely to be found during air raids in the dock or harbour were persons employed by the undertakers ; and where any such order is made—

(*a*) the order may contain such provisions as the appropriate department thinks proper, including provisions authorising the undertakers to do such of the following things as may be specified in the order—

(i) make increases in their charges as may be specified ;

(ii) to recover from persons using the dock such sums as may be determined by or under the order ;

(iii) to borrow on such terms as to security as specified.

(*b*) the provisions of this Act relating to the provision of air raid shelter shall not apply to any factories or commercial buildings in the dock or in the part specified in the order ; and

(*c*) no grant shall be payable for expenses incurred in the provision of air raid shelter in the dock or harbour.

(2) The measures specified in a notice may include measures designed to secure that the undertaking is capable of providing services which would not, apart from hostile attack or the danger thereof, be required to be provided by that undertaking ; and, in relation to any such measures the provisions relating to grants shall have effect as if for the reference to one-half of the approved expenses there were substituted seventeen-twentieths.

(3) There may be paid by Parliament towards approved expenses incurred by public utility undertakers in the collection of casualties and the treatment in first-aid posts, grants not exceeding one-half of those expenses.

SECTION **42.—Provisions as to Electricity Undertakings**

(1) The Central Electricity Board shall have power—

(*a*) to acquire, store, insure and maintain stocks of plant and equipment for temporary use in the event of hostile attack ;

(*b*) to make arrangements for the distribution thereof ;

(*c*) to acquire any land, property, and do anything necessary for any of the purposes aforesaid.

(2) The Central Electricity Board shall defray any approved expenses incurred by any other electricity undertakers in taking measures for securing the due functioning of their undertaking in the event of hostile attack and Parliament may pay to the Central Electricity Board towards—

(*a*) the expenses incurred by the Board under the preceding subsection ;

(*b*) the approved expenses of the Board incurred on the measures mentioned in subsection (1) ; and

(*c*) the approved expenses of the Board incurred on measures to secure the due functioning of their own undertaking;

grants not exceeding one-half of those expenses.

PART VI

OBSCURATION OF LIGHT AND CAMOUFLAGE

SECTION **43.—General Duty as to Factories, Mines and Public Utility Undertakings**

(1) It shall be the duty of the occupier of any general factory premises, of the owner of any mine and of the persons carrying on any public utility undertaking to take forthwith any necessary measures to secure that in the event of war throughout any periods of darkness—

(*a*) no light is allowed to appear from within any building on the premises or used for the purposes of the mine or undertaking; and

(*b*) no lights not within a building remain alight, unless they are essential for the conduct of work of national importance, are adequately shaded, are reduced in power and, save where the Minister otherwise directs, are capable of instant extinction at any time:

Provided that this subsection shall not apply to any light exhibited solely in the interest of navigation.

(2) The appropriate department may serve a notice in writing requiring the occupier, owner or persons to take such measures as are mentioned in subsection (1).

(3) This section does not apply to any of the matters dealt with in the next succeeding section.

SECTION **44.—Provisions as to Processes involving Flames or Glare**

(1) Where any process involves the emission of flames or glare not capable of being screened by means which would suffice in the case of ordinary lighting of a building, the appropriate department may serve on the occupier of the factory premises, the owner of the mine or the public utility undertakers a notice in writing requiring him or them to

complete such measures as may be specified to secure that the flames or glare will either no longer be produced during any period of darkness or will be wholly or partially screened.

(2) The Minister may serve on the owner of any mine in connection with which there is any accumulation or deposit of refuse which is burning or is liable to spontaneous combustion a notice requiring him to secure that no flames or glare will be produced during any period of darkness or that any flames or glare so produced may be wholly or partially screened.

Section 45.—Camouflage

The Minister may serve on the occupier of any factory premises a notice requiring him to take or complete such measures as may be specified to secure that the premises are less readily recognisable by aircraft.

Section 46.—Grants under Part VI

There may be paid out of moneys provided by Parliament towards the approved expenses of any person on whom a notice has been served under the two last preceding sections in taking the measures specified in the notice grants not exceeding one-half of those expenses.

Section 47.—Penalty for Failure to Comply with Notice

If any persons fail to comply they shall be liable to a fine not exceeding one hundred pounds, and if the failure continues they shall be liable to a fine not exceeding fifty pounds for each day on which the offence continues. A reasonable period from the date of the conviction may be fixed for the compliance with the requirements of the notice and where the Court has fixed such a period the said daily penalty shall not be recoverable for any day before the expiration.

Section 48.—Saving for Provisions of Part V

The preceding provisions of this Part of this Act relating to public utility undertakers shall not be construed as limiting the generality of the provisions of Part V of this Act, but no grant shall be made in respect of the same expenses.

Section **49.—Provisions as to Practice of Dimming Lights**

(1) Nothing requiring a local authority to cause the whole or any part of their area to be lighted shall render it unlawful for the authority to cause the lights in highways and public places in the area to be dimmed or extinguished for—

(*a*) training or exercising any persons in respect of air raid precautions ; or

(*b*) testing devices for enabling movement of traffic to continue in unlighted streets.

(2) Nothing shall render it unlawful for the occupier of any premises or any public utility undertaking to cause the lights in the premises or undertaking to be dimmed or extinguished for—

(*a*) assisting a local authority in training or exercising any persons in respect of air raid precautions ; or

(*b*) training or exercising persons employed in the factory premises, mine or public utility undertaking in respect of air raid precautions.

(3) This section shall be deemed to have had effect as from the commencement of the Act of 1937.

Part VII

Measures to Deal with Casualties and Disease

Section **50.—Powers of Minister of Health**

(1) It shall be part of the functions of the Minister of Health (referred to as " the Minister ") to make arrangements—

(*a*) to secure that war facilities will be available for the treatment in hospital of casualties occurring in Great Britain from hostile attack ;

(*b*) for the training in advance, in nursing, of persons who express willingness to offer their services in the event of war ;

(*c*) for the provision of a bacteriological service for controlling the spread of infectious disease in the event of war.

(2) In order to afford accommodation for the treatment in hospital of such casualties as aforesaid, arrangements aforesaid may provide for the removal in the event of a hostile attack

of sick persons, etc., from the place in which they are being treated and for their treatment or maintenance in some other place.

(3) For the purpose of any arrangements under this section, the Minister shall have power—

(*a*) to acquire and hold land, erect buildings and execute works;

(*b*) to acquire and hold medical stores and equipment, and do all such things as may appear to him expedient for the storage, preservation and transport of such stores and equipment;

(*c*) to enter into agreements with local authorities, governing bodies of voluntary hospitals and such other persons as he thinks fit.

(4) In relation to the acquisition of land the provisions of the Lands Clauses Acts, as amended by the Acquisition of Land (Assessment of Compensation) Act, 1919, are hereby incorporated with this Act.

(5) Any land, stores or equipment held by the Minister shall be held on behalf of His Majesty, and the Minister shall, subject to such conditions as determined by the Treasury, have power for any purpose to manage, sell, let or exchange any such land and to dispose of any such stores or equipment.

(6) The expression "treatment" does not include treatment in a first-aid post, and the expression "medical stores and equipment" includes stretchers, ambulances and any other articles which the Minister thinks necessary for the treatment of casualties from hostile attack.

Section 51.—Duties of Local Authorities

It shall be the duty of the council of every county and county borough—

(*a*) to provide for the storage and preservation of medical stores and equipment acquired by the Minister as the Minister may direct;

(*b*) to execute such works as the Minister may require for rendering any premises under the control of the council suitable for a hospital or for protecting persons in hospitals under the control of the council in the event of hostile attack;

(*c*) to hold at every hospital drugs and other medical stores and ward equipment as the Minister may direct so that the quantity shall not exceed—

(i) the quantity ordinarily used in the hospital in four weeks ;

(ii) in the case of beds and mattresses eleven-tenths of the number of beds ordinarily kept in the wards ;

(iii) in the case of bedding, six-fifths of the quantity required for the beds ordinarily kept ; and

(iv) in the case of other ward equipment, six-fifths of the quantity ordinarily kept.

SECTION **52.—Temporary Transfer of Officers**

(1) The Minister and the council or county borough may agree that the services of any officer of the council shall be placed at the disposal of the Minister, for such period and for assisting the Minister in the exercise of his powers under this Part of this Act.

(2) The service of an officer under the Minister shall be deemed to be service under the council for the purpose of the Local Government Superannuation Act, 1937.

SECTION **53.—Financial Provisions**

(1) All expenses incurred by the Minister shall be defrayed out of moneys provided by Parliament.

(2) In respect of each period of twelve months ending with the thirty-first of March, there shall be payable to the council who execute works in any of the works referred to in this part, a grant of whichever is the greater of the following two amounts—

(*a*) seven-tenths of the approved expenses incurred by the council in that period in the execution of those works ; or

(*b*) the amount by which such expenses exceed one-tenth of the produce of a rate of one penny in the pound levied in the area of the council for that period.

This subsection shall have effect with respect to the period ending with the thirty-first March nineteen hundred and thirty-nine and all subsequent periods.

(3) For the purpose of this section, the amount of the produce

of a rate of one penny in the pound for any period shall be ascertained in the manner required by paragraph three of the Schedule to the Act of 1937.

SECTION **54.—Powers conferred by this Part to be in Substitution for Powers under Act of 1937**

(1) The powers conferred from the Secretary of State under the Act of 1937 shall cease to be exercisable in so far as similar powers are exercisable by the Minister under this Part of this Act.

(2) No air raid precautions scheme shall make provision for the treatment in hospital of casualties or the training in advance of persons in nursing :

Provided that every local authority who make provision for treatment of casualties in first aid posts shall cause a suitable number of persons to be trained in nursing under the arrangements made under the preceding provisions by the Minister.

(3) Approval shall not be given under the Acts of 1937 to any expenditure of the local authority incurred under this Part of this Act in connection with matters for which provision cannot validly be made in an air raid precautions scheme.

SECTION **55.—Provisions as to Combinations of Councils**

(1) So much of this part of this Act as confers powers or imposes duties on the councils of counties or county boroughs shall be construed as confirming the like powers and imposing the like duties on any combination of councils existing for the purpose of the provision or maintenance of hospitals.

(2) Where any such combination includes the council of any county district, no part of the expenses of exercising powers or performing duties shall be borne by the county district and the share borne by councils of counties or county boroughs included in the combination shall be ratably increased accordingly.

PART VIII

MISCELLANEOUS

SECTION **56.—Evacuation of Civil Population**

(1) It shall be the duty of every local authority in accordance with the directions of the Minister—

(*a*) to furnish information for the purpose of assisting the population by His Majesty's Government of plans for the transference of members of the civil population from one area to another and for accommodation and maintenance ;

(*b*) to take in advance measures designed to facilitate transference or accommodation or maintenance of persons so transferred ;

(*c*) to provide, in such premises under their control as are reasonably available for the purpose, for the storage of equipment and material acquired by the Minister under this section ; and

(*d*) to take part in carrying out any such plan.

(2) Any local authority may serve on the occupier of any premises a notice requiring him to send to the authority particulars with respect to the premises and to the number of persons resident therein and any person who fails to comply shall be liable to a fine not exceeding £5.

(3) The Minister may make regulations .for securing accommodation and such regulations may—

(*a*) provide for occupiers of premises being required to furnish such accommodation specified ;

(*b*) declare the circumstances and extent to which responsibility shall be assumed by occupiers for the feeding and care of children accommodated ;

(*c*) authorise the imposition of fines not exceeding fifty pounds or imprisonment not exceeding three months for failure to comply.

(4) There shall be paid out of monies provided by Parliament to any local authority grants equal to the total amount of their expenses under this section.

(5) Any expenses incurred by the Minister in the acquisition and storage of equipment or any other material with a view to the accommodation and maintenance of the population transferred shall be defrayed by Parliament.

SECTION **57.—Requisition of Premises and Vehicles**

(1) The Minister may by order declare the provisions of this section to be in operation and—

(*a*) any local authority may take possession of any premises designated by them under Part II of this Act ;

(*b*) the Commissioners of Works may take possession of any premises which should, to meet the exigencies of the situation, be rendered available for use by any Government department ;

(*c*) any local authority having any civil defence functions may take possession of any vehicle and use it in the discharge of any of those functions.

(2) Where an order has been made the authority may remove any property which is in any premises or vehicles of which possession is intended to be taken, and may take such other steps as may be necessary for putting the premises or vehicle in a condition as will enable them to be used ; and any occupier who refuses and any persons who obstruct shall be liable to a fine not exceeding one hundred pounds.

(3) There shall be paid such compensation to such persons as Parliament may hereby determine.

(4) Possession shall not be retained after the expiration of three months from the date of making the order.

SECTION 58.—Special Provisions as to Supply of Water for Extinguishing Fires

(1) Any fire authority may submit to the Minister a scheme for securing that special supplies of water be available and for—

(*a*) the laying of mains and pipes for the conveyance of water ;

(*b*) the installation on bridges, embankments and other places adjoining any water (not being water contained in a reservoir), of pipes or other apparatus for enabling water to be withdrawn ;

(*c*) the acquisition of fire floats ;

(*d*) the construction of underground tanks.

(2) The Minister may approve with or without modifications any scheme submitted to him under this section and any such scheme being so approved shall come into force.

(3) There may be paid by Parliament towards the approved expenses incurred by any fire authority grants not exceeding nine-tenths of those expenses :

No grant shall be made unless—

(*a*) the works are completed before the end of September, nineteen hundred and thirty-nine, or

(*b*) the works are then in progress and the Minister is satisfied that they will be completed within a reasonable time thereafter.

Subsections (4) to (7) contain legal stipulations regarding the L.C.C. and water authorities.

(8) The Minister shall not approve any scheme unless it contains provisions for preventing—

(*a*) the contamination of any water supplied by water undertakers ; and

(*b*) the use for domestic purposes of any water conveyed in any main or pipe laid under the scheme.

SECTION 59.—**Power of Minister of Transport to acquire Plant and Materials for the Repair of Roads and Bridges**

(1) The Minister of Transport may acquire stocks of plant and material for the repair of roads and bridges damaged by hostile attack.

(2) The Minister of Transport shall have power to use or dispose of any plant or materials forming part of such stocks.

(3) The expenses shall be defrayed by Parliament.

SECTION 60.—**Power of Minister as to Stocks of Building Materials**

(1) The Minister may acquire stocks of plant and materials for repair of buildings damaged.

(2) The Minister shall have power to dispose of any plant or materials forming part of any such stock.

SECTION 61.—**Power of Minister to make Bye-laws with respect to Land used for Experiments with Explosives**

SECTION 62.—**Power of Local Authorities and Public Utility Undertakers to Appropriate Lands and Buildings for Purposes of Civil Defence**

(1)

(*a*) Any local authority having any civil defence functions or any public utility undertakers may use any lands

or buildings owned by, leased to, or under the control of the authorities or undertakers for the purpose of discharging any of those functions ;

(b) any local authority may permit any other local authority having any civil defence functions to use for the purpose any lands or buildings of the first mentioned authority.

(2) The powers conferred shall only be exercisable with the approval of the Minister.

(3) The Minister may at any time give directions that any use of any lands or any buildings under this section shall cease and may require the lands or buildings to be restored.

(4) The expression " use " in relation to lands includes the erection of buildings and the making of excavations.

Section 63.—Amendment of s. 5 of Act of 1937

Legal enactments.

Section 64.—Compulsory Hiring of Land

(1) Any county or county borough of the City of London and any metropolitan borough or county district may hire compulsorily any land for the purpose of the Act.

(2) The Minister shall make regulations for the purposes of this section.

(3) Land to which this section applies is unoccupied land and land in the occupation of a tenant whose tenancy thereof shall expire within three years after the making of the order.

Section 65.—Powers of Bodies Corporate as to Measures against Hostile Attack

Anybody carrying on any business or undertaking shall have power to take any such measures in relation to their business or undertaking as public utility undertakers are or can be authorised or required to take under any of the provisions of this Act.

Section 66.—Extension of Borrowing Powers of Trustees, etc.

(1) The provision of air raid shelter shall be deemed to be an improvement authorised by the Settled Land Act, 1925.

(2) Any liquidator or trustee in bankruptcy, receiver, committee or other person acting in a fiduciary capacity who is, as such, occupier of any premises shall, for the purpose of providing air raid shelter or complying with any obligation imposed on him by this Act, have power—

(*a*) to utilise any moneys in his hands in his capacity;

(*b*) to raise money by the sale or mortgage of any property vested in him;

and any money reasonably expended by him for the said purpose shall be allowed in account.

(3) Where the owner of any building is a mortgagee, he shall be entitled to add to his security any money reasonably expended by him under this Act as owner.

SECTION 67.—Property in Equipment, Appliances and Material provided by the Town or Local Authorities

(1) The property in any equipment, appliances or material free of charge shall remain in His Majesty.

(2) Any equipment, appliances or material used in the execution of work by a local authority under Part II or Part IV of this Act shall remain the property of the authority.

(3) Any person who, being in possession of any such equipment, appliances or material fails to use reasonable care for the preservation thereof shall be liable to a fine not exceeding five pounds.

(4) If any equipment, appliances or material which have been affixed to any premises are removed therefrom on behalf of His Majesty or the local authority, any damage shall be made good.

SECTION 68.—Penalty for Unauthorised Use of Uniforms, Medals and Badges

Any unauthorised person who uses or wears any uniform, medal, badge or emblem issued by or with the authority of the Minister for the use of persons engaged in any civil defence service, shall be liable to a fine not exceeding twenty pounds.

SECTION 69.—Provision of Air Raid Shelter not to increase Valuation for Rating

SECTION 70.—Enlargement of Scope of Town Planning Schemes

There shall be included among the general objects for which a scheme may be made under the Town and Country Planning Act, 1932, the object of rendering the whole or any part of the area to which the scheme applies less vulnerable to air raid.

SECTION 71.—Compensation in the event of Injury to Persons engaged in Air Raid Precautions Activities

(1) This applies to personal injuries sustained in the course—

(*a*) of being in air raid precautions ; or

(*b*) of being trained in nursing ; or

(*c*) of acting in a voluntary capacity on behalf of a local authority,

being injuries sustained in time of peace.

(2) The Treasury may provide for payment by Parliament to persons or the dependants of persons who suffer injuries, periodical or lump sums as may be specified.

(3) A scheme under subsection (2) may be revoked or varied.

(4) No compensation or damages shall be payable by the employer of the injured person.

(5) The expression "personal injury" includes death.

SECTION 72.—Directions to Local Authorities to Discharge Functions with respect to Air Raid Precautions

(1) The Minister may direct any local authority to discharge functions with respect to any matter which could be included in a scheme made by that authority, whether or not a scheme providing for that matter has been made.

(2) The council of any county may direct the council of any county district in that county to discharge such functions.

(3) If the council of a county fail to give any direction, the Minister may give the direction himself.

(4) It shall be the duty of a local authority who receive a direction to discharge the functions specified.

SECTION 73.—Power to Transfer Functions of Defaulting Authority

If the Minister is satisfied that any local authority have failed to discharge any functions which they are required to

discharge under this Act he may make an order transferring the functions to himself.

PART IX

Supplemental

Section 74.—Determination of Claims to Compensation and Increases of Rent

(1) Any question relating to the amount of compensation under this Act shall be referred to and determined by official arbitrators appointed for the purposes of the Acquisition of Land (Assessment of Compensation) Act, 1919.

(2) The reference Committee may make rules and prescribe the fees to be paid.

Section 75.—Supplementary Provisions as to Appeals to Minister

(1) The Minister may make rules as respects the appeals to him—

(*a*) specifying the manner in which the appeals are to be brought;

(*b*) authorising persons to be appointed to inquire into the matters raised and to report to the Minister;

(*c*) authorising any person so appointed to take evidence on oath;

(*d*) making provision as to the costs incurred;

(*e*) otherwise regulating the procedure to be followed.

(2) If the Minister considers it just so to do, he may extend the time limited by this Act for the bringing of an appeal.

Section 76.—Rules as to Form of Reports

The Minister may by rules require that reports under this Act shall be made in such form and include such particulars and intimation as may be specified.

Section 77.—Penalty for False Statements

Any person who in any report made by him under this Act makes any statement which he knows to be false shall be liable

to a fine not exceeding one hundred pounds or imprisonment for a period not exceeding three months or to both.

SECTION **78.—Criminal Liability of Directors, Officers, etc.**

Where an offence punishable under this Act is committed by a body corporate and is proved to have been committed with the consent or connivance of any director, manager, secretary or other officer of the body corporate he, as well as the body corporate shall be deemed to be guilty and shall be liable to be punished accordingly.

SECTION **79.—Power of Factory Inspectors and Local Authorities to enter Premises and Penalty for Obstruction**

(1) Any inspector or person duly authorised by authority having any civil defence functions shall, on producing some duly authenticated document showing his authority, have a right to enter any premises at all reasonable hours for the purpose of—

(*a*) ascertaining whether there is or has been any contravention of or failure to comply with the provisions of this Act;

(*b*) ascertaining whether or not circumstances exist which would authorise or require any action to be taken under this Act;

(*c*) otherwise facilitating the performance by the authority of their civil defence functions.

(2) The provisions of sub-sections (2), (3), (4) and (5) of section two hundred and eighty-seven of the Public Health Act, 1936, shall apply for the purposes of this section.

(3) Any person who wilfully obstructs any inspector or any persons duly authorised by the Minister or authority in the exercise of any right conferred by or by virtue of this section, shall be liable to a fine not exceeding five pounds.

SECTION **80.—Service of Documents**

Any document required or authorised may be given or served either—

(*a*) by delivering it to that person;

(*b*) by leaving it; sending it in a prepaid letter addressed to him at his last known residence or place of business;

(*c*) by the description of "occupier" of the premises to which it relates and delivering it to the premises or by affixing it to some conspicuous part of the premises.

SECTION **81.—Exemption of Certain Works from Building Bye-laws**

No requirements or restrictions imposed by or under any enactment, as to the erection of buildings or means of access or as to the submission of plans or the giving of notices to a local authority shall apply in relation to any works executed under this Act by a local authority or any person on advice given by or as a result of a notice by the appropriate authority.

SECTION **82.—Covenants to Repair and Reinstate not to apply to Works executed under this Act**

SECTION **83.—Financial Provisions**

(1) Any administrative expenses of any Government department under this Act shall be defrayed by Parliament.

Sub-sections 2–5 relate to the method of payment.

SECTION **84.—Special Provisions as to London**

Any reference in this Act to a local authority or fire authority shall, in relation to any part of the administrative county of London, be construed as a reference to such one or more of the following authorities, that is to say the London County Council, the Common Council of the City, the Council of any Metropolitan Borough, the District Surveyor, and the respective overseers of the Inner Temple and the Middle Temple, as may be specified in that behalf by an order of the Minister.

SECTION **85.—Consultation with Joint Committees under Act of 1937**

Where the functions of a Council in submitting air raid precautions schemes are exercised by a joint Committee, the Council shall, before exercising any function under this Act, consult with the joint Committee.

SECTION **86.—Exercise of Powers of Board of Trade**

Anything required or authorised by this Act to be done by the Board of Trade may be done by any person authorised in that behalf by the President.

SECTION **87.—Saving for Telegraphic Lines**

Section 6 of the Telegraph Act, 1878 (which empowers the Postmaster General to establish telegraphic lines in certain undertakings) shall apply to the underground air raid shelters, premises and parking places.

SECTION **88.—Provisions as to Orders, Regulations, etc.**

Any Order in Council under this Act may be revoked or varied by a subsequent Order in Council.

SECTION **89.—Definitions of "Factory," "Factory Premises," "Mine" and Commercial Building**

(1) In this Act the expression "factory" means a factory within the meaning of section one hundred and fifty-one of the Factories Act, 1937:

Provided that—

(*a*) the said expression does not include any premises in the occupation of the Crown;

(*b*) the expression does not include any factory entirely situate in a building not wholly occupied by the occupier of the factory;

(*c*) where part of a factory is situate in a building not wholly occupied by the occupier of the factory, that part shall be deemed for the purposes of this Act not to form part of the factory.

(2) Where there is a factory in which more than fifty persons work—

(*a*) the factory; and

(*b*) the remainder of any building in which the factory or any part thereof is situate; and

(*c*) any land contiguous to the factory which is in the occupation of the occupier of the factory and any buildings on that land,

shall together be deemed to constitute factory premises for the purposes of this Act :

Provided that—

(*a*) no building wholly or mainly occupied as a hotel or restaurant (other than a restaurant carried on for the use of persons working in the factory) shall be deemed to form part of any factory premises ;

(*b*) no mine shall be included in any factory premises ;

(*c*) no premises which are wholly occupied by public utility undertakers shall be deemed to be factory premises for this Act.

(3) In this Act the expression "mine" means a mine or quarry in or about which more than fifty persons work, and not being part of factory premises.

(4) Where any factory premises are contiguous to a mine and are occupied by the owner of the mine,

(*a*) if the number of persons working in the mine exceeds the number of persons working in the factory the premises shall be deemed to form part of the mine ;

(*b*) if the number of persons working in the factory exceeds the number of persons working in the mine, the mine shall be deemed to form part of the factory.

(5) In this Act the expression "commercial building" means a building in which more than fifty persons work, not being—

(*a*) a building wholly or mainly occupied as a school, college, university, hotel, restaurant, club, place of public entertainment or amusement, hospital or nursing home ; or

(*b*) a building wholly occupied by public utility undertakers for the purpose of their undertaking :

Provided that—

(i) no building which forms part of any factory premises or mine shall be deemed to be a commercial building ; and

(ii) any residential part of a building shall, if it is provided with a means of normal egress from the building which is not available to occupants of the non-residential part of the building, be disregarded for all the purposes relating to commercial buildings.

(6) In relation to the provisions of Part III of this Act

relating to the training of employed persons, this section shall have effect as if for the words "fifty persons" wherever they occur therein, there were substituted the words "thirty persons."

(7) For the purposes of this Act the number of persons who work in premises shall be taken to be the greatest number of persons present at any one time :

Provided that—

(*a*) regard shall not be had to any temporary increase occasioned by a change of shifts ;

(*b*) in the case of outdoor workers, regard shall not be had to more than twenty-five per cent. of their total number.

(8) The number of persons who work in or about a mine shall be the number who are simultaneously present in or about the mine otherwise than below the surface.

Section **90.—Other Provisions as to Interpretation**

Various definitions.

Section **91.—Application to Scotland**

This section deals with the necessary alteration in wording to cover the application of the Act to Scotland.

Section **92.—Provisions as to Northern Ireland**

The provisions of this Act shall not extend to Northern Ireland.

Section **93.—Short Title and Citation**

This Act and the Act of 1937 may be cited together as the Civil Defence Acts, 1937 and 1939.

SCHEDULES

First Schedule

Part I. Financing of certain expenditure of Central Electricity Board and distribution of burden thereof among electricity undertakers.

Part II. Disposal of property acquired by Central Electricity Board under sub-section (1) of the principal section.
Part III. Miscellaneous provisions.

SECOND SCHEDULE

Modifications of Lands Clauses Acts.

THE AIR RAID SHELTER CODE

References to this code and interpretation thereof have been made constantly throughout the present volume, but for the convenience of the reader a digest of the code itself is given hereunder.

STATUTORY RULES AND ORDERS, 1939, NO. 920

AIR RAID SHELTERS FOR PERSONS WORKING IN FACTORIES, MINES AND COMMERCIAL BUILDINGS

REVISED CODE

August, 1939

(*Section* 13 *of the Civil Defence Act*, 1939)

DIGEST OF SCHEDULE

Revised Code (*Section* 13 *of the Civil Defence Act*, 1939) *for the Guidance of Occupiers and Owners of Factory Premises, Factories, Mines and Commercial Buildings, and other Persons concerned.*

PART I

REQUIREMENTS WITH WHICH SHELTER MUST COMPLY

1.—Definitions

For the purposes of this Code—

" Air Raid Shelter " means protection otherwise than by war-like means or by any article of apparel, from hostile attack from the air, and " an air raid shelter " means any premises, structure or excavation used to provide air raid shelter.

"Trench shelter" means a shelter in the form of a covered trench or tunnel which is covered with earth to a thickness of at least 12 in. at every part.

"Accommodation" relates to the number of persons accommodated.

"Prescribed stresses" shall mean the maximum permissible working stresses specified,

(*a*) in respect of reinforced concrete, in the "Recommendations for a Code of Practice for the use of Reinforced Concrete in Buildings,"

(*b*) in respect of steel, in B.S.S. No. 449–1937,

(*c*) in respect of pressures on load-bearing concrete and masonry (brick and stone), in B.S.S. 449–1937,

(*d*) in respect of timber, in "By-laws for the Use of Timber" made by the London County Council, 1937.

"Sound brickwork" means brickwork consisting of sound, well-fired clay bricks, sand-lime bricks complying with B.S.S. 187–1934 for building bricks Class A, or cement concrete bricks having a crushing strength of not less than 1,500 lb. per sq. in., properly bonded and jointed in mortar set and hardened.

"Brickwork in cement mortar" means brickwork consisting of bricks as described above, bonded and jointed in cement mortar not weaker than one volume of cement to three volumes of sand, or in cement lime mortar not weaker than two volumes of cement, to one of lime to nine of sand.

"Sound stonework" means coursed stone masonry in sound condition.

"Ordinary concrete" means concrete mixed in the proportion of not less than 112 lb. of cement complying with B.S.S. No. 12–1931 or B.S.S. No. 146–1932 to 12 cu. ft. of suitable coarse and fine aggregate measured as combined.

"Structural concrete" means concrete, consisting of not less than 112 lb. of cement to 2½ cu. ft. of suitable fine aggregate and 5 cu. ft. of suitable coarse aggregate.

"Reinforced concrete" means structural concrete, reinforced with not less than 2 lb. of steel of which at least 0·7 lb. is distribution steel per cu. ft. of concrete.

2.—Lateral and Overhead Protection

An air raid shelter must give

(*a*) Lateral protection by means of not less than :—

(i) $1\frac{1}{2}$ in. thickness of mild steel plate or plates,

(ii) 12 in. thickness of reinforced concrete,

(iii) $13\frac{1}{2}$ in. thickness of sound brickwork or sound stonework,

(iv) 15 in. thickness of ordinary or structural concrete, unreinforced,

(v) 2 ft. thickness of ballast or broken stone,

(vi) 2 ft. 6 in. thickness of earth or sand, or

(vii) a corresponding aggregate thickness of a proportionate combination of such materials.

and (*b*) Overhead protection, subject to protection from falling debris, by not less than :—

(i) $\frac{1}{4}$ in. thickness of mild steel plate.

(ii) 4 in. thickness of structural concrete reinforced if and as necessary or otherwise suitably strengthened or effectively supported.

(iii) 6 in. thickness of ordinary concrete, reinforced if and as necessary or otherwise suitably strengthened or effectively supported.

(iv) concrete in hollow type construction conforming with the requirements in the Appendix to Part I.

(v) $8\frac{1}{2}$ in. thickness of arching in sound brickwork or sound stonework.

(vi) 1 ft. 6 in. thickness of ballast, broken stone or earth.

(vii) a corresponding aggregate thickness of a proportionate combination of such materials, or

(viii) a substantial building overhead consisting of a roof and not less than two floors (including that covering the shelter) where such structure is enclosed with walls of brick, stone or concrete.

Provided that other approved materials may be used.

In an external air raid shelter wholly or partly above ground, the overhead protection must be such as to be a dead weight of

not less than 60 lb. per sq. ft. or must be fastened down to resist an upward force of 300 lb. per sq. ft.

The lateral protection must extend throughout the height and the overhead protection must extend over the whole area of the shelter.

Provided that in a shelter wholly above ground where the aggregate area of door and window openings in any one wall of a shelter compartment does not exceed one-quarter the surface area of such wall and the total width of such openings does not exceed one-third the total length of such wall, it shall suffice if the protection in such openings extend to a height of 6 ft. above the floor of the shelter, subject to movable protection being provided to the space above, such timber shutters 2 in. thick or mild steel shutters $\frac{3}{16}$ in. thick or other approved material or it shall suffice if the openings are protected by screen walls giving the lateral protection under section (2), situated not more than 12 ft. from the wall and extending beyond such openings to prevent the entrance of splinters. This requirement will be complied with where the extent of such screen beyond the opening is not less than its distance from the opening.

3.—Protection from Falling Debris

Adequate protection must be afforded from falling loads due to the collpase of any structure over a shelter or within a distance from such shelter equal to one-half the height of such structure, by the provision of a floor or by the strengthening of the existing floor or by a suitable roof based on an estimated static loading as representing the effect of impact, to the satisfaction of the Minister.

Provided where such loads would not include heavy machinery, materials and goods of abnormal weight nor chimney-shafts, towers, heavy colonnades, pediments or cornices, but would comprise only the loads of a normal structure and superimposed loading of ordinary goods or light plant and equipment, it shall suffice if the falling loads be deemed to be static loads in accordance with the following :—

(*a*) For buildings wherein the loads are carried on load-bearing brickwork or stonework :—

Number of Storeys at a Higher Level than the Top of the Shelter.	Minimum Static Load (in addition to the Floor Load) to be assumed to represent the effect of the Debris. lb. per square foot of Floor Area.
1 or 2	200
3 or 4	300
over 4	400

(*b*) For steel or reinforced concrete framed buildings the debris load may be assumed to be a static load of 200 lb. per sq. ft. of floor area (in addition to the floor load) irrespective of the number of storeys over.

4.—Stability

All new constructions in connection with air raid shelter must be so executed that all loading occasioned thereby shall be safely sustained and transmitted to the ground without exceeding the prescribed stresses.

Except in hard rock or other self-retaining materials, trench shelters must be provided with linings consisting of concrete, brickwork, steel (suitably protected from corrosion), or any other suitable material.

Where such trench shelter is at a distance from any building or structure of not less than one-half the height of such building the stresses in the lining of reinforced concrete or steel may exceed the prescribed stresses by 25 per cent.

5.—Gas-proofing

Every shelter for more than twelve persons must be constructed to permit its being rendered gas-proof without structural alteration.

6.—Space required in Shelters

(1) (*a*) in the case of a shelter accommodating not more than twelve persons, or (*b*) in the case of a trench shelter having openings at both ends into the open air, it must have for every person a floor area of $3\frac{3}{4}$ sq. ft.

(2) In the case of a shelter not permanently sealed

against gas, and ventilated by natural means, or by mechanical means at a rate of not less than 150 cu. ft. of air per hour, per person, it must have, for every person,

not less than 6 sq. ft. of floor area,
not less than 50 cu. ft. capacity,
not less than 25 sq. ft. of surface area of all walls backed by earth, other walls not less than 8½ in. thick, floor and ceiling or roof.

Provided the area, capacity or surface may be less subject to—

(*a*) the shelter being ventilated mechanically at 450 cu. ft. of air per hour for every person and provided arrangements are made for emergency operation of the ventilating plant, when 3¾ sq. ft. for every person will be sufficient.

(*b*) the shelter being entirely below ground level has abnormally massive construction with dividing walls not less than 3 ft. thick and heavy slabs or vaulting over not less than 3 ft. in thickness at any part inclusive of any solid filling, subject to authorisation of the Minister.

(3) An unventilated shelter accommodating more than twelve persons and permanently sealed during the period of occupation must have, for every person,

not less than 6 sq. ft. of floor area,
not less than 50 cu. ft. capacity,
not less than 75 sq. ft. of surface area of all walls backed by earth, other walls not less than 8½ in. thick, floor and ceiling or roof.

Every trench shelter shall have a horizontal floor and a clear head-room, measured therefrom, of not less than 6 ft. extending throughout the length of such shelter.

7.—Limits of Accommodation

Every shelter should, wherever possible, be divided into sections or compartments for not more than 50 persons.

Every trench shelter to accommodate more than 50 persons must be divided into sections. In a continuous trench such divisions must be effected by a change in direction through an angle of 80 to 100 degrees and extending in the new direction a

distance of not less than 5 ft. subject to such distance being not less than 25 ft. in the case of a second change of direction involving a return parallel to and opposite the first section.

In any other shelter for more than 200 persons, compartments must be formed by the erection of dividing walls extending the full height of the shelter. If such compartments accommodate not more than 50 persons each of the dividing walls must be of reinforced concrete not less than 12 in. thick or of sound brickwork or sound stonework not less than $13\frac{1}{2}$ in. thick in cement mortar.

If such compartments accommodate more than 50 persons the dividing walls must consist of either :—

(*a*) reinforced concrete 24 in. thick, or

(*b*) two walls, each of reinforced concrete 12 in. thick or of sound brickwork or stonework $13\frac{1}{2}$ in. thick, with a space between not used as a shelter.

No compartment may accommodate more than 200.

8.—Accessibility of Air Raid Shelter

Every shelter must be boldly marked and so situated and accessible by day and by night that persons may pass from work to their shelter within 7 minutes.

9.—Entrances and Exits

Every shelter shall have a 2 ft. 6 in. wide entrance.

Every shelter for more than 12 persons must have at least two exits as remote as may be practicable from each other, one of which may be the normal entrance. One exit must give access to the open air and when possible be free from the danger of falling debris. Where the emergency exit gives access to another shelter the opening must not exceed 3 ft. 6 in. in height nor 2 ft. 9 in. in width.

All reasonable measures must be taken to afford one entrance or exit proper protection from falling debris.

10.—Drainage

Adequate arrangement must be made to keep every shelter free from water.

11.—Sanitary Facilities

Every shelter must have proper closet facilities at the rate of not less than one seat per 25 persons and subsidiary buckets and urinals as necessary.

12.—Lighting

Every shelter must be lighted, independent of the normal lighting service. Where generators or large storage batteries are employed they must be isolated and have separate ventilation.

13.—Dangerous Pipes, etc.

Pipes, tanks or containers which might prove a source of danger must not be permitted in any shelter, and water pipes and gas pipes must be provided with valves where they pass through any shelter.

Appendix to Part I

Rules for Hollow Types of Floor conforming with Standard Overhead Protection

(*a*) hollow tiles or hollow concrete blocks of a maximum width of 12 in., embedded between reinforced concrete ribs of width not less than 2 in. or one-quarter of the width of the tiles or blocks, whichever is the greater, or

(*b*) precast reinforced concrete structural units of a maximum width of 12 in., with or without supplementary ribs of reinforced concrete deposited in situ or supplementary steel in the joints between the units,

and which in each case (*a*) and (*b*) has, above the system of tiles, blocks or precast units not less than 3 in. of reinforced concrete, or alternatively not less than 2½ in. of reinforced concrete, together with a superimposed screeding not less than 1 in. thick.

Part II

Advice as to Incidental Matters and as to Methods to be followed in providing Shelters

Each case must be treated individually, and advice on the best method of treatment should be sought from engineers or architects qualified.

Layout of Shelters

Wherever possible, shelters should be spaced at least 25 ft. apart, measured in the clear.

Shelters within buildings should wherever practicable be placed below ground level or at ground floor level and due regard should be given to the nature of existing structures on the site.

Fig. 243 illustrates some characteristic sources of danger to be avoided in the layout of shelters in industrial buildings.

Area A should be avoided since injury to exposed columns and stanchions would lead to the collapse of the building

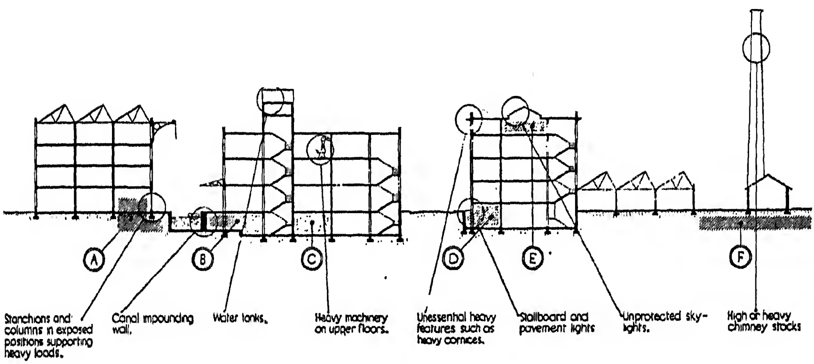


Fig. 243.

resulting in heavy debris loads, and the provision of satisfactory emergency exits would be difficult.

Area B is unsuitable for shelter, firstly because it might be rapidly flooded if the canal wall were injured, and secondly because it would be liable to be crushed by the fall of the heavy water tank.

Area C is unsuitable because of its immediate proximity to the base of the water tank, and because it will rarely be economical to strengthen the roof to withstand the fall of heavy machinery.

Area D would require special protection of pavement and stallboard lights on account of the possibility of collapse of the heavy cornice and parapet, which again would make the problem of emergency exits particularly difficult.

Area E. Inflammable construction or the storage of inflam-

mable material immediately under the glazed roof would present a fire hazard which might endanger the whole building.

Area F immediately at the base of a large chimney-stack is unsuitable for the provision of shelters.

Steam boilers, large refrigerating plants, large furnaces, oil tanks and chemical storage tanks would endanger life near them if they were fractured and their immediate vicinity should be avoided in laying out shelters.

The code concludes with a section dealing with typical shelters generally as explained in Chapter X.

CHAPTER XIII

THE RESPONSIBILITIES OF THE LAYMAN

THE provision of air raid shelters, according to Government decree, is left in the hands of local authorities and individual occupiers of premises. The Government has, however, offered to assist schemes for air raid shelters, prepared by local authorities and approved by the Home Office by paying up to 85 per cent. of the cost exceeding the amount that would be met by a penny addition to the rates.

In order to speed up the work of providing suitable refuges for the 45 million odd urban population of this country each citizen must play his part in loyal co-operation with the Government and local authorities.

In order to minimise the risk to an unprotected civil population the German Government has enforced measures whereby public undertakings and proprietors of works, factories, and large business houses are obliged to provide scientifically constructed shelters for their employees and organise first aid, relief and anti-fire services. Inspection and exercise in their use are carried out regularly. Each industry undertakes to see that its members comply with the Government's instructions, the Air Ministry exercising central control.

In this country the ever free Briton is left to co-operate with the authorities on a voluntary basis and true to his nature is exhibiting a lamentable apathy to the whole question. He quite sensibly is unmoved by the alarmist but on the whole he does not take A.R.P. seriously enough.

Conditions are not as they have been for centuries past. *We will not have time* to muddle through to ultimate victory. The attack from the air will not be a mere three-minute raid but a sudden intense concentration, which directed against the courage of our people will continue unceasingly for a week or more until *if we are unprotected* complete demoralisation will result.

Panic, our worst possible enemy, must not be permitted. You, Mr. Householder, positively *must* determine to " stand-fast " and hold your family sanely to courageous fortitude in an emergency.

Can you voluntarily discipline yourself to this truly important *rôle* ?

Do not doubt it. Many an individual openly admitting to a high degree of " wind up " has proved himself a " stout fellow " and an example in an emergency, merely through the expedient of *doing something useful.*

Your patriotic duty, then, is to learn what to do. There is no better way than enlisting with the voluntary A.R.P. Workers, of which approximately one to each ten households are required as a minimum. You may join in the district in which you work or in which you live. Indecision and delay is an evasion of your civic responsibilities.

You may be willing to stake your own life on a bet that there will be no war, but dare you stake also the lives of your wife and children and the lives of your employees ?

What have you done for your family ?

Have you not yet improvised a refuge ?

Have you not yet practised with a mask ?

Are the children quite at home in the shelter ?

Have they not been encouraged to familiarise themselves with its occupation ?

Have you cleared the loft of inflammable or combustible material ?

Have you installed any fire protection ?

Are you ready with appliances to deal with the incendiary bomb ?

And what about a reserve supply of preserved food for use when the normal supplies temporarily fail ?

And have you thought how best to carry on with your job even when your usual train, tram or bus fails to serve you ?

And what about your pets ?

Have you thought out resourceful ways of meeting these contingencies ?

Have you yet done *anything* to help yourself and your family to meet emergency conditions ?

Do not delay. Preparation for passive defence now will

minimise the risk of attack almost in proportion to the thoroughness of the measures you undertake.

Determine to be self reliant, help yourself and your less fortunate neighbour ; do not expect your local authorities or the national services to function expressly for you !

In abnormal emergency conditions it is your patriotic duty to Help Yourself !

How about your staff at the office or works ?

Have you a cut and dried A.R.P. Scheme ?

Are each man's duties defined and have you yet had any exercises ?

Do not rely upon evacuation. You cannot hope to have an opportunity to scuttle out to the country. The warning will be too short, besides which transport demands will be excessive and normal organisation cannot be expected to stand the strain.

The roads will not be passable to your car, even if they are free of defence service transport. Panic and congestion on the roads would account for countless casualties which would be avoided by the simple expedient of taking cover wherever you may be.

A chance bomb crater on a road would hold up traffic for hours and machine gunning of main exits from the Metropolis is to be expected in a raid.

To sum up the Civilians' patriotic duty is to *prepare now* against the worst, which may thus be avoided altogether.

CHILDREN

The Board of Education have issued a circular (No. 1461, dated January 3rd, 1938) on " Air Raid Precautions in Schools " and in which they state—

> " The responsibility of determining the arrangements which are best suited to the circumstances of particular localities or schools is primarily one for the Local Education and School Authorities in consultation with the local Air Raid Precautions authorities, and the measures to be adopted in particular areas will need to be co-ordinated with the general scheme of protection for the locality as a whole,"

and go on to set down notes for the assistance of those concerned.

Emphasising that the primary consideration must be the safety of the children they point out that each Authority will wish to consider whether in the conditions likely to prevail in its area at such a time it will be reasonable to expect parents to allow their children to continue to attend school.

Evacuation to safer districts and dispersal to private houses or even camps is being arranged in some cases. In other cases where the risk is not so great schools kept open will be under strict A.R.P. discipline and children will carry their masks to and from school. Anything in the nature of gas drill except in real emergency is deprecated by the board, but responsible teachers are urged to train themselves in technical methods of protection, decontamination, etc., under the A.R.P. Services and in First Aid.

Structural A.R.P. are contemplated only in exceptional cases as schools in districts liable to attack would in all probability be evacuated and utilised as first aid posts under passive defence schemes.

ANIMALS AND AIR RAIDS

Generally

Animals are very susceptible to injury in air raids and apart from direct injury from high explosive bombs or burns from incendiary bombs the effects of gas on animals can be very distressing and is more often than not fatal.

General Richteur, Veterinary-General of the German Army, stated that when a tank of phosgene exploded at Hamburg all the animals, both wild and domestic, were destroyed within a range of several miles.

The whole subject of chemical warfare and animals is a very involved one engaging the close attention of the authorities. In the absence of official pronouncements on the question, the following notes are proffered in the confident hope that they will be of assistance to those seeking guidance on the subject.

That animals will be the deliberate target of air raiders is generally unlikely but herds of dairy cows and concentrations of food animals at markets and ports might be the subject of attack. It is, however, quite evident that domestic animals

retained in urban areas would be involved in the results of an air raid equally with the civil population and being unable to help themselves would no doubt suffer to a greater extent.

As in the case of the citizen the best defence for the animal is dispersal and evacuation. As, however, it is unlikely that warning of a raid would be received sufficiently early to permit of orderly evacuation or even immediate dispersal, it is necessary for us to consider NOW what steps are to be taken to reduce animal suffering in the event of air raids.

The Royal Society for the Prevention of Cruelty to Animals has prepared a leaflet giving directions concerning first aid to animals injured in an air raid and as is well known, the Society has 220 inspectors throughout England and Wales, and their services would naturally be available in cases where animals were injured and had to be destroyed. Co-operation could no doubt also be arranged with the Veterinary Profession for the treatment of such animals.

The People's Dispensary for Sick Animals have seventy-three dispensaries all equipped to take in sick animals of the poor and a man will be constantly on duty in a gas-proofed shelter. All people in an emergency are encouraged to bring their animals to the dispensaries where they will have every attention. The P.D.S.A. has done sterling work in the interests of the health of animals and are preparing protective measures to be employed in air raids, suitable for the local conditions.

The Zoological Society are also investigating the matter and the Home Office have the question of the protection of animals under consideration.

Unfortunately at the time of going to press the findings of the various Committees are not available and the following are therefore the author's own notes and views on the subject.

Animals in the Rural Districts

Large concentrations of animals in the country should be avoided under air raid emergency conditions and dispersal should be arranged over as wide an area as possible. If gas attack is expected low lying and confined pastures should be shut off and the high ground of the open country used in preference.

Any pasture which has been affected by Mustard Gas or

similar persistent gases should be shut off from cattle until properly decontaminated. This can best be effected by spraying with a decontaminating solution of diluted bleach and exposed preferably to rain and sun before cattle are allowed again to enter.

Forage suspected of being contaminated with gas should be burnt, but where possible forage should be stored in well protected concrete silos.

Farm roads should preferably be constructed of concrete to facilitate decontamination and hosing down. Dipping baths for the decontamination of animals are recommended and the animals should be well washed with water both before and after the bath.

Harness of horses may require decontamination and should preferably be kept in a gas-proofed store.

Hay lofts over stables should be cleared to minimise fire risks and rapid means of escape for horses from bombed stables should be provided.

Concrete floors and stall partitions are hygienic, permanent and fire resistant.

Cows, hens and other farm stock should have gas-proof barns provided for them and if the farm is a large and conspicuous one or its situation adjoins an important town likely to be bombed with high explosive the farm buildings and barns should also be splinter proofed.

Unless it is possible to splinter-proof roof constructions of farm buildings the sandbagging or other splinter resisting construction need not be carried to a height of more than 8 ft. from the ground.

The fire-proofing of all buildings housing animals in an air raid is highly desirable, especially if panic and wholesale destruction is to be avoided.

The fresh air requirements of animals is of considerable importance and the minimum space required for each as well as the surface area necessary for the dissipation of heat must be investigated and adequate provisions made.

Comparisons of the Respiratory Exchanges of Animals and Man

The Respiratory exchange is the exchange of gaseous substances taking place between the organism and the sur-

rounding atmosphere. Oxygen is constantly absorbed by animal organisms and carbon dioxide is expirated. Respiratory exchange is the combustion within the body and by which carbon and hydrogen of the animal tissues are combined with oxygen to form carbon dioxide and water. The gas exchange is utilised in three main directions :—

1. To establish the carbon balance of the organism.
2. To determine the nature of the substances catabolised.
3. To measure the total catabolism.

This last is ascertained by colorimetry which indicates the total energy transformation independent of the metabolic process.

Muscular movements increase metabolism considerably and nervous excitement, body temperature, condition of activity of digestion, etc., all have their respective influences. From the experiments of Tigersteadh, Loewy and Voit it would appear that warm-blooded animals at rest and quiet stand in the following approximate relation :—

TABLE XCIX

Animal.	Average Weight in Kilogrammes.	Total Calories in 24 hrs.
Horse	445	8,450
Pig	128	2,430
Man	70	2,240
Dog	15	1,050
Goose	3·5	233
Cat	2·5	200
Rabbit	2·2	160
Hen	1·5	123

The figures in the last column are approximately proportional to the relative amounts of fresh air required by each, and as the calories per square metre of surface area per 24 hours is the average of 1,000 for each animal the capacities of closed shelters can be calculated from the figures tabulated overleaf.

TABLE C

	NORMAL.		CRUSH.	
Animal.	c.f.m.	Total Area in sq. ft. for 9 hrs. Occupation.	c.f.m.	Total Area in sq. ft. for 3 hrs. Occupation.
Horse . .	1·35	340	0·74	230
Pig . .	0·39	100	0·22	67
Man . .	0·36	90	0·20	60
Dog . .	0·17	42	0·095	28
Goose . .	0·04	10	0·022	7
Cat . .	0·03	8	0·017	5½
Rabbit . .	0·025	7	0·014	4¾
Hen . .	0·02	5	0·011	3⅓

The capacities for closed ventilated shelters can be calculated from the minimum requirements given in the following table :—

TABLE CI

	NORMAL.		CRUSH.	
Animal.	c.f.m.	Floor Space, sq. ft.	c.f.m.	Floor Space, sq. ft.
Horse . .	9·5	50	3·8	35
Pig . .	2·7	25	1·1	10
Man . .	2·5	6	1·0	3·5
Dog . .	1·2	8	0·5	3
Goose . .	0·28	6	0·11	3
Cat . .	0·22	5	0·09	2½
Rabbit . .	0·18	4	0·07	2
Hen . .	0·14	4	0·06	2

Until the results of experiments being carried out by interested authorities are available it is not known to what extent animals of different classes would panic under the abnormal conditions obtaining in a closed shelter and under the noise of a bombardment.

It will therefore be advisable to allow a considerable margin on the minimum figures given above.

ANIMALS IN URBAN DISTRICTS

Generally

If any warning is received of the outbreak of hostilities arrangements should at once be made to evacuate as many as possible of the animals to rural areas. It will, in any event, be wise to clear all domestic animals from off the streets and to accustom them to occupy shelters which can be suitably protected.

The following figures taken from a census of Greater London in 1937 show the astonishing number of animals that there are in urban areas :—

TABLE CII

ANIMALS IN GREATER LONDON

Horses	40,000	
Cattle	9,000	
Sheep	6,000	
Pigs	18,000	
Dogs	400,000	(licensed)
Cats.	1,500,000	(estimated)

On receipt of a warning or when you consider the outbreak of hostilities imminent do not hasten to have domestic animals destroyed but seek the advice of the National A.R.P. Animal Committee, Gordon Square, St. Pancras, W.C.

The leading animal welfare societies have pooled their transport and resources to form a committee under Col. R. J. Storey, head of the R.S.P.C.A. veterinary unit in the Abyssinian war.

The Committee have issued the following recommendations to owners of pets, for emergency measures :—

(1) Send them into the country in advance of war.

(2) Equip dogs with muzzles and leads.

(3) If travelling by public conveyance, cats should be in baskets.

(4) If you decide to keep your pets with you find out the name and address of the nearest veterinary surgeon or animal welfare centre. (The police have the information.)
(5) Remember—animals will not be permitted to enter public shelters.
(6) If you leave at short notice, in no circumstances leave your animals in the house or turn them loose.

Horses

There are a million and a quarter of horses in this country and 200,000 of these are employed in transport work principally in urban districts. In London one milk firm alone employs nearly 5,000 so that the urgent need for a scheme for protection is readily apparent.

Gas masks for horses as illustrated in Fig. 55 were employed during the war but they do not as a rule take kindly to them. Many animals regard them as nosebags and endeavour to find something to eat in them. Masks greatly impede the flow of air to the lungs and horses should not be required to work in them. They should not be made to run and when wearing masks should be frequently rested.

Although lacrimators do not appear to affect the eyes of horses the mask only protects the nostrils and the upper jaw. Horses are therefore liable to contamination and injury from mustard gas, particularly on the pasterns and fetlocks.

This was the experience in the war and horses were so badly burned and blistered that they had to be destroyed.

Animals which are required to traverse ground suspected of being contaminated with vesicant gases should be provided with gas protective puttees or leggings of oilskins.

If contaminated areas must be crossed and leggings are not available, smear anti-gas ointment No. 2 (consisting of chloramine-T in a vanishing cream base) on legs below knee and hock joints, especially in the hollow of the heel.

Avoid undue splashing by walking horses and when clear of the contaminated areas wash off ointment with hot water and soap.

The provision of complete suits of oilskins for horses, donkeys and mules would not be attempted outside the circus

ring and is not a practical solution of the problem. It is undoubtedly best to shut up the animals in gas-proofed stables with at least two attendants to each twelve beasts.

It would not be advisable to accommodate more than twelve in each stable and these should preferably be in stalls. Larger stables should be subdivided into individually gas-proof compartments.

A desirable size would be 40 ft. × 27 ft. × 12 ft. high (average) giving 2,880 sq. ft. in walls and roof and if this building were completely sealed the safe period for occupation would be about three hours when twelve horses and two men were inside.

It must be remembered that it will not be possible to open up the stable for ventilation until the gas is clear of the vicinity or gas masks have been fitted.

The stables at the large P.D.S.A. Sanatorium at Ilford are being rendered gas proof, and full arrangements have been made to deal with any emergency which might arise either for animals or the staff.

If the stables described above were ventilated with, say, 150 c.f.m. of fresh and filtered air, twelve horses and two men could occupy the protected stable practically indefinitely. Independent water and protected food supplies would however be necessary and the men would have to operate the filter-ventilator continuously. All protected stables should have air-lock entrances at least 10 ft. long.

The danger of fire and the difficulty of rescuing animals from burning premises needs no emphasis.

It is often better to cover horses' heads with split sacks or large pieces of cloth to make them more tractable when being led from a burning stable, whilst the use of the R.S.P.C.A. quick release slip-hook in securing the animals in stables or byres facilitates their rescue.

When there is cause to anticipate an emergency, all equines working in large towns should be provided with a 12 ft. lead worn round the neck conveniently coiled for rapid release and fitted with a halter under the bridle.

In an emergency, the lead is released its length, allowing the driver to unharness the animal whilst still keeping it under control. A nosebag slit down the back and provided with a

zip fastener enables some feed to be offered without removing halter, harness bridle or bit, thus allaying possible panic.

The horse should be tied to a heavy vehicle away from danger of falling *débris* of buildings.

Horses should not be tied to railings, lamp-posts or Belisha beacons and should never be secured with the reins or to the bit.

Cattle

Dairy cattle accommodated in urban districts need special care and attention. Not only do the protective measures indicated for the horses require to be undertaken but special precautions to prevent possible contamination of milk supplies must be observed. Cows eat gas masks fitted to them.

Special regulations will no doubt shortly be issued by the Milk Marketing Board and the author will not presume to anticipate the form that they will take.

Sheep

Sheep are particularly susceptible to injury from vesicant gases and to contamination of their wool from pasture subjected to persistent gas. They should be accommodated in an emergency in gas-proofed and otherwise protected barns with shepherds to attend and operate the filter-ventilator. Their space and air requirements are approximately the same as those for the pig.

Pigs

The normal space required for a pig, sow and litter is 12 ft. × 9 ft., but in an emergency forty pigs could normally be accommodated in a barn having 1,000 sq. ft. of floor space and having an average height of 12 ft. With two men attendants these animals would probably safely occupy the barn completely sealed up for three hours.

The same barn ventilated with 150 c.f.m. filtered fresh air would accommodate forty pigs and two men attendants almost indefinitely.

The crush capacity being 100 pigs and two men with 150 c.f.m. for, say, six hours or more if really necessary.

Dogs

Gas masks for specially trained messenger dogs were used successfully during the war but as the masks cover the whole head or at least the eyes, nose and mouth, ordinary dogs soon become quite uncomfortable in them.

As the energy of respiration is not very vigorous, especially in the case of the smaller dogs, the filter canisters on the masks need to be exceptionally large and heavy to minimise air resistance.

The use of masks on dogs is therefore not generally recommended and owners are advised to take their dogs into gas-proof shelters with them. The most important point is to prevent the dog from running about, thereby using up excessive quantities of oxygen. Loud explosive sounds are painful to dogs which soon become terrified in the noise of a bombardment. It is therefore unwise to leave them unattended.

Whatever course is decided upon should be put into operation without delay in order to train the dog to accustom itself to the new conditions. A gas-proof kennel, designed by a member of the P.D.S.A. Technical Staff, is manufactured by Messrs. Boulton & Paul Ltd., of Norwich.

The kennel is complete with two regulation filters (as used on human gas masks), stale air outlet valves, and bellows. Purchasers are advised to use the kennel immediately in order that the animal may become used to it. It is essentially an indoor kennel, and can be used as an ordinary peace-time kennel in which the animal can eat and sleep. One simple movement of sliding out the floor and closing the gas-tight door converts it into a perfectly safe gas-proof chamber providing the animal with fresh filtered air for an indefinite period. This is done by means of bellows which operate by the weight and even slight movements, breathing, etc., of the animal, and these bellows are compensated by special springs.

Model A. Suitable for animals weighing from 8 to 52 lb. Kennel, 3 ft. 4 in. long, 1 ft. 10 in. wide, 2 ft. 6 in. high.

The price of the kennel is £3 10*s*. unpainted, in white wood, or £3 15*s*. oak stained.

The P.D.S.A. does not make any profit from the sale of these kennels, but they have come to an arrangement with the manufacturers, whereby for every few kennels sold, the

P.D.S.A. receive a free kennel which they are arranging to pass on to persons who cannot possibly afford to buy—such as the very poor.

These kennels can be ordered either from the P.D.S.A., 14 Clifford Street, London, W., or from Messrs. Boulton & Paul, of Norwich.

Kennels for large numbers of dogs should be gas-proof and at least two men attendants to each fifty dogs employed continuously.

In ventilation 70 c.f.m. would be required for such a kennel which provided with independent water supply and protected food store could be occupied continuously for an indefinite period.

The P.D.S.A. kennels at the Sanatorium at Ilford could house their normal capacity of dogs in safety during an air attack, and without fear of panic. The P.D.S.A. only treats sick animals whose owners cannot afford professional treatment or if professional treatment is unobtainable, and it is interesting to note that during 1938, a million cases of suffering animals of the poor received free treatment by the Society in their 104 dispensaries.

Cats

These animals present a difficult problem as considerable suffering may be caused them if any attempt is made to accustom them to gas masks. They should be kept in the house at night when raids are expected so as to avoid loss of time and patience in looking for them prior to retiring to the shelter. They do not consume large quantities of oxygen and should therefore be taken into the family shelter during a raid.

Small Farm and Domestic Animals

These should be accommodated in protected barns in small groups not exceeding fifty and provided with space and air generally to the scale laid down in the foregoing tables. In every case the number of the attendants should not be less than two so that in the event of the incapacitation of one of them the other could carry on.

Pigeons

Birds are exceedingly susceptible to the effects of poison gas.

Impregnated flannelette bags were provided for gas protection of pigeons in the war. The bags 15 × 15 × 25 in. were a close fit over the cages with a draw string at the top. Pigeons should be released at once if they are unable to be suitably protected.

Parrots and other Pet Birds

These should be protected from gas with impregnated covers to cages generally as described above and should be taken to the family shelter immediately upon the commencement of the air raid or on receipt of warning.

Do not desert your animals in an emergency. Caring for them is a great help to one's own stability, and if they are injured take them at once to the R.S.P.C.A. clinics or to the nearest veterinary surgeon. Those who cannot afford professional treatment are advised to go to one of the P.D.S.A. Dispensaries. These dispensaries will, however, be available to all in a national emergency.

Take the precaution of finding out the nearest address now !

FIRST AID TO INJURED ANIMALS

H.E.

Splinters and flying fragments cause wounds, resulting in loss of blood, and serious bleeding is a real danger to the life of an animal.

Struggling increases the danger, and small animals can be rolled in a sack and the legs tied together.

Place a wad of cotton wool soaked in Friars Balsam on wound and bind tightly with antiseptic dressing. Profuse bleeding may be controlled by the application of a tourniquet above the wound, but this should never remain tight for more than one hour.

Gas

"Tear and nose irritants" produce no serious effect on animals, the "choking" gases are dangerous and "blister" gases usually fatal.

TREATMENT

(Contamination with Mustard Gas.)

(*a*) Swab with petrol and wash thoroughly with soap and warm water.

(*b*) Well rub in protective ointment (equal parts of bleaching powder and vaseline) and wash off thoroughly within three minutes ; or

(*c*) Wash thoroughly with frequent changes of warm water and soap.

Wash out eyes with plain warm water or salt water (one teaspoonful to 1 pint) and put few drops of medicinal paraffin in eyes.

(Contamination with Lewisite.)

Well scrub with hot water, soap and soda.

Treat eyes as for mustard.

Burns or blisters should be treated by a veterinary surgeon.

In minor cases of ordinary burns and scalds apply strong cold tea and afterwards dust over with flour.

Animals injured beyond reasonable hope of recovery should be speedily dispatched with a humane killer. (See R.S.P.C.A. pamphlet 326.)

THE FACTORY OWNER—RESPONSIBILITIES

Schemes for Factories

It is urged by the Home Office that all factories should prepare an A.R.P. scheme, and the particulars as to this are to be found in Handbook No. 6.

In order to meet an air attack successfully certain A.R.P. services are essential, and provision should be made for the following :—

(*a*) *Fire.* Considerable augmentation of existing fire services will be necessary to deal with the incendiary bomb menace. A number of small parties equipped with Redhill apparatus and stirrup pumps will usually be required.

(*b*) *Medical.* First aid arrangements and *personnel* will require to be increased, and the *personnel* should have training

in dealing with gas casualties. Arrangements must be made for the cleansing of *personnel* who may be contaminated with liquid gas. (*Vide* Appendix D, A.R.P. Handbook I.)

(*c*) *Decontamination.* *Personnel* will be required to carry out decontamination of material and must be trained and equipped for this work.

(*d*) *Rescue Work.* Parties should be trained for the rescue of *personnel* who may be trapped in damaged buildings.

(*e*) *Repairs.* It is advisable to have trained *personnel* to carry out urgent repairs to buildings and to plant.

When preparing such a scheme, close touch must be kept with the Local Authority as anything which is done by the factory as regards A.R.P. preparations must be co-ordinated with the Local Authority Scheme.

It is pointed out by the Home Office that even poor protection is better than none at all, and that if everyone in the factory knows where to go and what to do in an emergency, panic should be avoided, and the more complete the scheme as regards detail, the smoother it will work should it be required to put it into operation. Rehearsals, as carried out for boat drill on board ship, are very valuable for ensuring such smooth working.

It is also pointed out that the preparation of an Air Raid Scheme does not mean the inevitability of an air raid any more than the taking out of a fire insurance policy means the inevitability of a fire.

It is considered that with the aid of A.R.P. Handbook No. 6 it should be quite possible for most firms to prepare schemes for their factories, but in the event of difficulties being encountered, such firms are advised to consult the A.R.P. department.

THE TOWN PLANNER—OPPORTUNITIES

From time immemorial considerations of military defence have influenced the planning and layout of towns, and to-day the need for the adaptation of town planning to suit the requirements of passive defence against aerial attack is stronger than ever. Long term town planning constitutes the most far-sighted civil defence policy of all, and a thorough survey of the whole of the country is badly needed, with the object of providing the professions with an enlarged and up-to-date

ordnance survey of towns and their environs, showing underground railways, services, drains, etc.

Under section 70 of the Civil Defence Act, 1939, it is necessary to include among the general objects for which a scheme may be made under the Town and Country Planning Act, 1932, the object of rendering the whole or any part of the area to which the scheme applies less vulnerable to air raids.

The present urban congestion which renders our cities particularly vulnerable to attack from the air must be relieved by urban reconstruction and judicious decentralisation.

Various proposals have from time to time been put forward.

One is to distribute the whole of the population over the country in small detached units of buildings equivalent to a spacing of some hundreds of yards between units and thus by complete decentralisation dispersing all urban targets and reducing danger from the air to negligible proportions.

Such a scheme pre-supposes a very highly developed system of communication and transport but involves the complete sacrifice of urban civilisation and of industrial economy. An unpopular and impracticable scheme.

Other town planning proposals involve the concentration of huge populations in sky-scraper buildings widely spaced with the object of facilitating economic industrial and commercial pursuits without encroaching upon the preserved open spaces between units.

Such an arrangement would appear to be the reverse of the ideal from the point of view of passive defence as the buildings would be conspicuous—casting a huge shadow which cannot be camouflaged—would present a large vertical wall and horizontal roof target, would be the first buildings to be evacuated in a raid or would create untold panic in its many thousands of population who normally require some hours to vacate the building.

Properly to design such buildings to resist complete collapse under aerial bombardment would involve prohibitive costs, and the fire risk in the sky-scraper would be greatly increased.

As in the planning of shelters the smaller the unit the less the risk, and it would therefore appear that the construction of "satellite" towns not exceeding, say, 50,000 inhabitants, and each planned in accordance with the latest principles of town

planning as a complete and self-contained community spread over about 4 square miles, would meet the most urgent need of decentralisation and would afford facilities for the expansion of industries at present inadequately catered for in congested premises in cities.

Local authorities at present in difficulties regarding the provision of the necessary rehousing need no longer adopt the unpopular multi-storey flat building on expensive urban sites if they were to establish dormitory suburbs as part of the general scheme of decentralisation.

Ten million of the population of this country still require to be rehoused !

What an opportunity for the town planner !

The urban replanning envisaged would necessarily take a decade or more in its execution and what therefore must be done in the interim if a reasonable degree of protection is to be afforded the citizen in an air raid of any magnitude ?

At the time of going to press Sir Samuel Hoare, Home Secretary, had disclosed in Parliament that an invulnerable and secret battle headquarters would be established for the Whitehall departments in the event of war, that time-tables had already been worked out to move three and a half million of the population of London by rail fifty miles from London in seventy-two hours (without tickets), that about another two million would have trench or dug-out accommodation in the 8,100 acres of open spaces in London, and that evacuation of school children with their teachers has been worked out in detail. Private house owners are urged to place their basements and cellars at the disposal of the public and the construction of shelters is an urgent necessity.

Base line hospitals are planned on the outer ring of London, and in the event of war Oxford and Cambridge colleges may be taken over to house the casualties cleared from the hospitals.

THE ARCHITECT—RESPONSIBILITIES

In the Civil Defence of the nation very considerable responsibilities devolve upon the architect, and there is no excuse nowadays for designing a new building to be constructed in such a manner as to render it unsuitable for adaptation to the passive defence of the occupants ; indeed, in some continental

countries it is against the law so to construct new buildings.

As pointed out on page 196, the adoption of the features in building design desirable from the point of view of passive defence need not involve a cost which is additional to that of an ordinary building of the same accommodation. It is the patriotic duty of architects to induce their clients who intend to construct large buildings to adopt a flat roof containing a roof garden which will afford protection against incendiary bombs and may at the same time enable many acres of market gardening area to be re-established in the city. Except on expensive and restricted sites basements are often omitted but the desirability of constructing basement shelters which can be used for storage purposes in peace time should be emphasised.

In modern suburbia the basement has become a rarity, but in the future architects should include in all housing proposals an adequate number of shelters designed for the dual purpose of ordinary peace time use or emergency occupation in a raid.

The shelter room shown on Figs. 159 and 160, the strengthened basement on Fig. 115, and the lean-to shelter on Fig. 125 all offer appropriate means of attaining this end.

Greater attention should be given to fire-resisting construction and if timber is used in roofs and floors this should be fireproofed or covered with a fire-resisting medium.

As in the case of multi-storey buildings roof gardens afford a high degree of protection against the incendiary bomb, whilst the installation of gas-proof doors and windows should be normalised.

Services—gas, water, electric light and main drainage are collectively installed and are obviously a modern development which cannot be abandoned. In emergency conditions, however, bulk supplies from large installations are a source of danger and should be supplemented where possible with independent service units to each building.

Sanitary services to cesspits and soakaways should be installed with the permanent shelter, and emergency water supplies through a tank normally kept clean, and connected to the water system should be arranged.

Independent electric lighting should be installed and ventilation arrangements provided for the shelter.

In the case of existing buildings for which the architect is responsible, careful survey should be made with a view to ascertaining the necessary size and the best location for the air raid shelter; the strength of the roof should be investigated and arrangements made for appropriate protective measures against the incendiary bomb to be installed.

Owners of buildings unsuitable for adaptation should be notified with the minimum of delay in order that a nearby shelter may be constructed for the occupants.

The demolition or repair of buildings damaged or partially demolished in an aerial bombardment will demand the exercise of the trained skill of the architect, and already the foreshadowed provisions of the Civil Defence Act have thrown upon the architectural profession a rapidly increasing demand for his services in the design of shelter protection.

The Professional Advisory Committee (Shelters) of the Home Office Air Raid Precautions Department has drawn up a panel of architects, engineers and surveyors, with the aid of the respective recognised professional institutions. The members of the panel will act as consultants when required in the execution of the Government's shelters policy.

In addition, twelve Regional Professional Advisory Committees have also been set up, and it is to be hoped that a more progressive and planned approach to the solution of the Civil Defence problem will result from this action.

THE STRUCTURAL ENGINEER—PROBLEMS

The investigation of the strength of existing buildings and the design of bomb-proof shelters is undoubtedly the responsibility of the structural engineer who, working in collaboration with the architect, can best advise upon the measures to be taken in safety in construction and the adaptation of buildings.

In designing new work he should employ the accepted principles of anti-seismic construction and should apply the principles of design for shelters with bomb-proof structures as outlined generally herein.

In strengthening works careful calculations regarding the elastic deflection of the existing structure will need to be made

so as to ascertain by how much the old work will have to be wedged or jacked up to ensure that the new work takes its fair proportion of the load *before the existing structure is overstressed.* Works of this nature are more difficult to design and execute than are new works, and must therefore be entrusted to competent engineers.

CHAPTER XIV

"CAMOUFLAGE"

Introduction

The Landscape in modern war contains a collection of footprints which lead or mislead, and as the Airman to-day is the eye of the enemy, intelligence is largely the result of the contest between the photographer and the camoufleur.

In order to understand the principles of camouflage by means of which objects may be rendered inconspicuous it is necessary first to consider the optical laws upon which recognition depends.

An opaque object presents to our eyes the appearance of a patch of colour or of a number of colours against a background. Its shape is conveyed by the shape of the outline and the light and shade is an indication of the contour of its surface. The form of its shadow is also an indication of its shape and the brightness of its colouration a characteristic of its appearance.

Visible form can only be distinguished when it exhibits differences of colour or tone and light and shade compared with the background against which it is observed.

A reduction in the above-mentioned differences results in the object being less recognisable and the complete absence of these differences a complete lack of recognition through visual observation.

In nature the struggle for existence and the problems of self-preservation with which all animals are faced has resulted in specialised methods of offence and defence.

"For instance, we see evidence of this in the evolution of speed, on land, in the air, and under water, by pursuer and pursued; in the use of stealth and surprise, of deception and ambush; in the display of warning signals or of alluring baits; in the elaboration of smoke screens, traps, nets and parachutes; in retreat by burrowing underground or by the adoption of nocturnal habits; in the development of poison, and of deadly apparatus in the form of fangs or stings for its injection into the

bodies of enemies or prey, in protection afforded by plated or spiny armour; and in the use of chemical warfare which is practised, for instance, by certain insects, and of poison gas, by creatures like the skunk.

Of all these various adaptations—which, it will be noted, each have their parallel in the paraphernalia of modern warfare—perhaps none is so important, so widely distributed, or so perfect as that which renders animals inconspicuous, and often well-nigh invisible, in their natural surroundings." [171]

A study of camouflage in nature has shown that the four fundamental principles involved are—

(1) *Shadow elimination* by orientation or structural adaptations.

(2) *Counter-shading*, by which high lights are darkened and shadows are lightened so as to reduce the light and shade which discloses the form and contours of the surface.

(3) *Colour resemblance* both in colour and tone between the object and the background against which it is seen.

(4) *Disruptive colouration* due to a superimposed pattern of brightly contrasting colours serving to distract attention and conceal the outline.

Skiagraphy is the whole art of camouflage against aerial observation from the height at which anti-aircraft guns force enemy craft, as colour of itself hardly counts. Whatever colour is seen from this height is greyed by atmospheric effect and photographic tone value is of more importance than mere colour.

"*Form*" camouflage is exemplified in the "stick" insect (see Fig. 244) and "*Colour*" camouflage by the "leaf" insect (Fig. 245). *Adaptability* to natural surroundings may be realised by a study of the chameleon.

Counter-shading forms the basis for the colouration of innumerable creatures such as birds and reptiles (Fig. 246) and *Disruptive Colouration* by brilliantly contrasting colours with a disruptive pattern is to be seen in the giraffe, boa constrictors, etc. (Fig. 247).

Disruptive and *Coincident* patterns as in the frog are used to contradict the underlying structural features, the former to separate optically a continuous structure and the latter to unite to the eye surfaces contiguous but structurally separate.

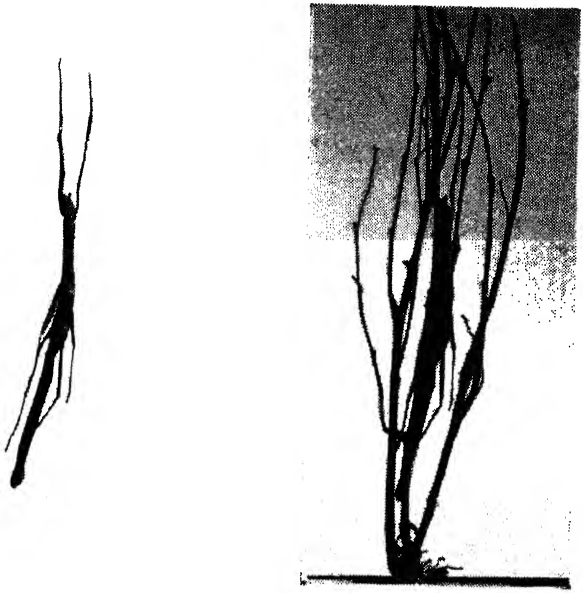


FIG. 244.—The "stick" insect, exemplifying "form" camouflage.

(*Courtesy Silicate Paint Co. Ltd.*)

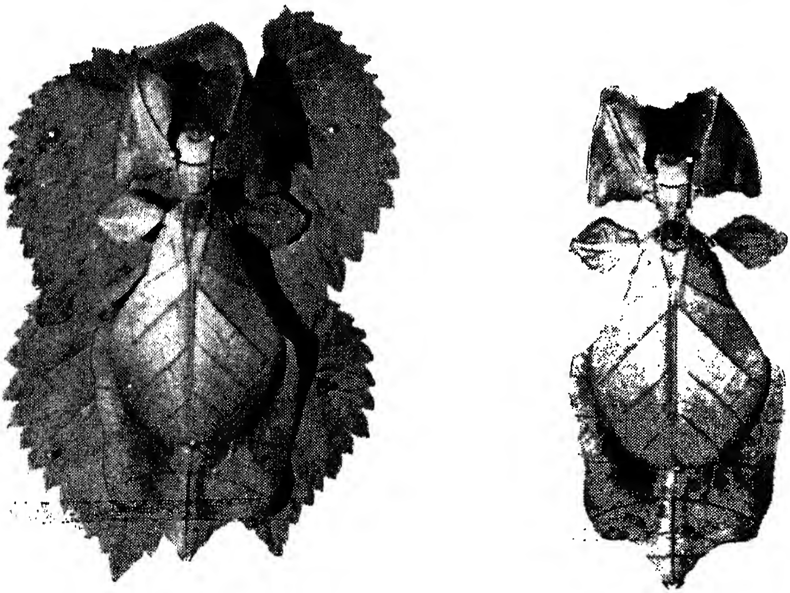


FIG. 245.—The "leaf" insect, showing nature's employment of colour in camouflage.

(*Courtesy Silicate Paint Co. Ltd.*)

[*To face page* 556.

FIG. 246.—Coincident colouration of sitting woodcock. Camouflage by imitation.

FIG. 247.—The adder's outline obliteration camouflage by mimicry.

(*Courtesy Jenson & Nicholson Ltd.*)

Dazzle utilises violent contrasts of tone rather than differences in colour with a view to obtaining disruptive contrast and outline obliteration as exemplified in young ringed plovers.

Camouflage by dazzle must be executed boldly and with confidence as at close range objects so treated will appear glaringly conspicuous.

Haphazard application of blotches of paint as on army vehicles is useless as the colours blend to an even tone when viewed from a distance.

Texture is as important as colour in the production of tone values as textured light absorbent surfaces look darker at a distance than a flat tone of the same colour.

Imperfect camouflage is very incriminating and the camoufleur must constantly forestall detection by the expert reader of aerial photographs, who is practised in detecting the false from the real and the natural from the artificial in views from an altitude of 10,000 ft. or more.

Aerial reconnaisance can only be satisfactorily met with concealment from above or confusion and deception where complete concealment is not possible.

Camouflage is a strategical matter depending upon the points of view of others and can be divided into classes roughly as below.

TABLE CIII

- Camouflage (Day)
  - Military
    - Strategic
      - Far seeing camouflage of the ground as a prelude to vast concentrations of men and material.
    - Tactical
      - Concealment for the immediate needs, and constantly changed to minimise risk of detection, erection of dummy positions.
  - Naval
    - Concealment of manœuvres by smoke screen
    - Dazzle painting of ships in inverted perspective, changing apparent course.
  - Aerial
    - Camouflage of craft.
  - Civil
    - " Invisible " Construction
    - Ground Pictures
      - Camouflage of buildings
        - Construction of dummies.

TABLE CIV

Camouflage (night)

- Prevention of glare
- Obscuration of light.
- False flashes
- Lighting of dummy positions.

GENERAL PRINCIPLES

Strategic Camouflage

If aerial photographs of the area to be dealt with are first taken a model of the work can be prepared and the exact features of the covered site reproduced on the roofs and camouflage covers.

Any false or dummy constructions should be made *first* and all activity on the real site concealed under road covers and hangars carefully coloured to represent the original undisturbed site.

The Germans in the Great War covered miles of roads and acres of fields with rigid hangars coloured and modelled to represent the original scenery, carried out the work without detection and accommodated divisions of men and equipment under them.

They also successfully concealed great military activity in orchards and fields covered with open squares of cellulose fibre material on wire.

In their modelled scenery system they kept everything low and avoided shadow by sloping all edges down at an angle not exceeding 15 degrees to the horizonal (see Fig. 248). Covering of painted canvas is not so suitable as rigid roofs which offer more scope for artistic resourcefulness and if necessary the planting of quick growing crops.

Tactical Camouflage

Adaptable camouflage suitable for quick installation to satisfy the needs of the moment is most conveniently arranged in the form of a fishing net flat top cover. Stretched taut over any object to be concealed and threaded more and more thinly towards the edges with tufts of grass, rags, etc., the elimination

of a hard and definite shadow is possible thus rendering the form of the object covered inconspicuous from the air.

The hard opaque system lacks portability and convenience in installation and is consequently not so suitable for tactical military camouflage.

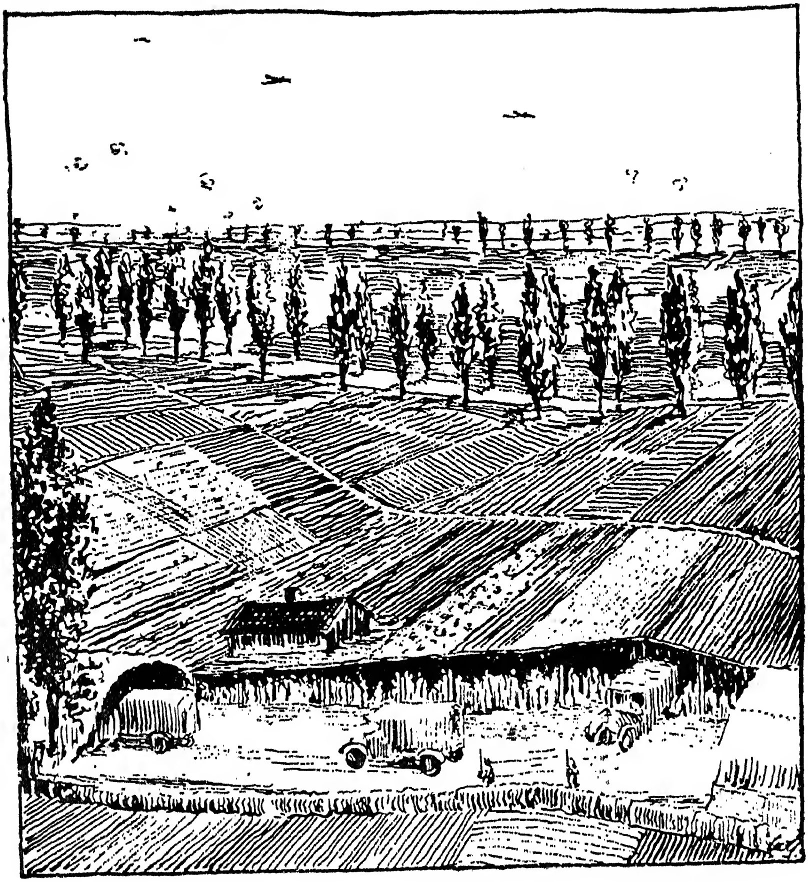


FIG. 248.—Cut-away view showing extensive modelled scenery camouflage adopted by the Germans in the Great War. Roads and fields were covered with rigid hangars coloured to represent the undisturbed countryside.[164]

Naval Camouflage—Smoke Screens

The concealment of manœuvres by smoke screen is an expedient which made the Zeebrugge raid possible and the

smoke barrage is now an accepted tactical ruse for both land and marine use.

From time to time proposals have been made to the effect that the wide use of smoke candles in a city would render accurate bombing into it impossible. Smoke producing agents costing but a few shillings apiece fired simultaneously at about 200 yards centres on an arc about the town and up-wind of it, would it is claimed, produce a thin smoke screen sufficient to prevent position finding by aircraft, but not sufficiently dense to hamper traffic or tactical movements on the ground. The official view is that such a scheme would be too unreliable and costly ; and in any event the use of smoke would hamper anti-aircraft activities and render observation of bombers from the ground much more difficult if not impossible.

Applications of Camouflage in Civil Defence

The purpose of camouflage is to make the bombing of a specific target as difficult as possible.

The exact position of a target may have been learned from the study of maps, aerial photographs and other sources of intelligence, but in the end the bomber on a raid is dependent upon direct visual observation for accurate bombing.

If then the camouflage renders the target unrecognisable at a distance of several miles, observation of it may come too late to be of use to the bomber unless he returns and exposes himself again to the local active defence.

Such natural guides as rivers and woods or railways, roads or canals in the vicinity of a large industrial establishment would be of less assistance to an air raider if the establishment itself be effectively camouflaged.

The Bomber's View of the Target

Consideration of the average weather conditions in this country (bright intervals with sky half covered with clouds) forces the conclusion that as a bomber needs a continuous view of the target for accurate bombing he would be forced to descend below the clouds. Say between 5,000 and 7,000 ft. Again considering his speed of approach (possibly 200 miles per hour) and allowing for the appropriate trajectory and for " dead time " in bomb sighting and aiming calculations, the bomb

aimer would first need to spot the target when some five miles away and when his angle of vision would be approximately 13 degrees to the horizontal (see Fig. 249).

The distance and low angles of observation have a dominating influence upon camouflage designs and emphasise—

(*a*) The necessity of adopting bold patterns in design.

(*b*) The desirability of collaboration between camoufleurs of adjoining premises.

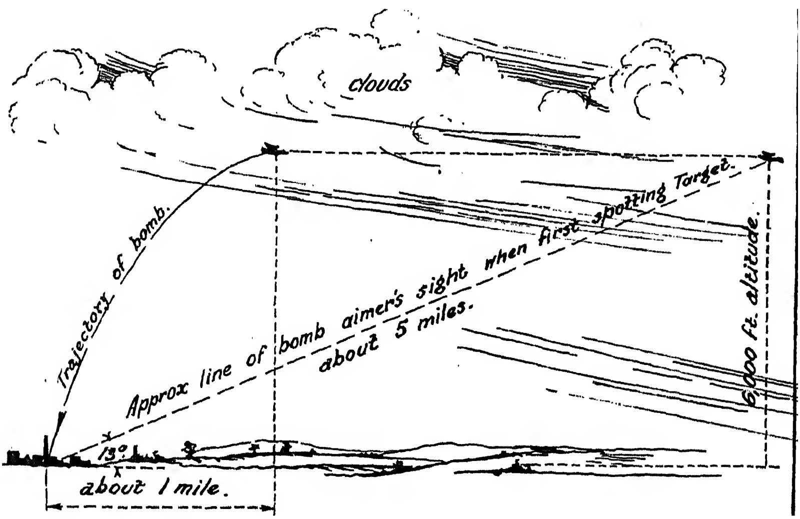


FIG. 249.—Bomb aiming. Diagram showing distance from which target must first be located if accurate bombing is to be possible.

(*c*) The realisation of the facts that objects smaller than 6 ft. each way are not separately visible at five miles range; and

(*d*) At the lower angles of vision reflection from flat roofs is very marked.

Let us then consider first the appearance of an uncamouflaged target viewed along a line of sight at 13 degrees to the horizontal.

Orientation of Target

The orientation of the target, the direction of approach to it, and the time of the day all have a bearing upon its appearance

from the air and Figs. 250 and 251 show an industrial establishment situated in the latitude of the midlands, oriented so that its major axis is north and south and as seen in early morning and late afternoon respectively, the observer approaching from the south-east.

The same establishment oriented east and west and approached from the south-east would have the appearance in the morning as shown in Fig. 252, and in the afternoon as shown in Fig. 253.

Notice the change in the shadows from morning to afternoon and the subtle differences in tone between surfaces variously lighted. With the sun behind the observer there is less contrast in the picture and recognition from a distance will not be so easy as when the object is cross-lighted such as in B. and D.

When flying southwards " into the sun " the observer will see flashes reflected from the roof glazing, and pronounced reflections from the flat roofs if these factors are not properly dealt with in camouflage.

Form

In the disguise of buildings, especially those of large bulk, the form of the outline is usually indicated to an observer by the shape of the shadows. Apart therefore from the employment of tone and colour (*infra*) the elimination or the disguise of shadow is of paramount importance.

Elimination of Shadow

Properly to understand the difficulties of the elimination of shadow one must study the laws of light and shade and appreciate the subtle tone differences between a horizontal and an oblique plane.

Fig. 254 shows a building with flat roof subjected to lighting from the top left-hand corner of the illustration and seen obliquely from above.

The top with the light full upon it shows the lightest tone, the near side a tone darker and the third visible side, more in shadow, the darkest tone on the vertical sides. The marked shadow on the ground clearly confirms its shape and renders it very conspicuous from above.

With canvas sides sloping gradually to the ground at an

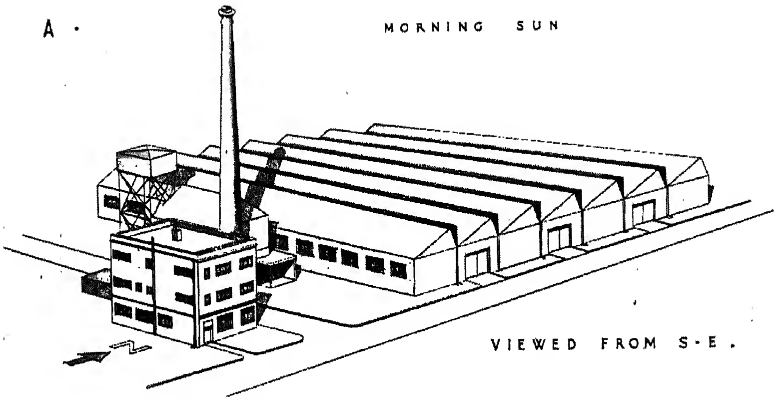


FIG. 250.—Factory oriented N. and S. and viewed from the S.E. under the morning sun.

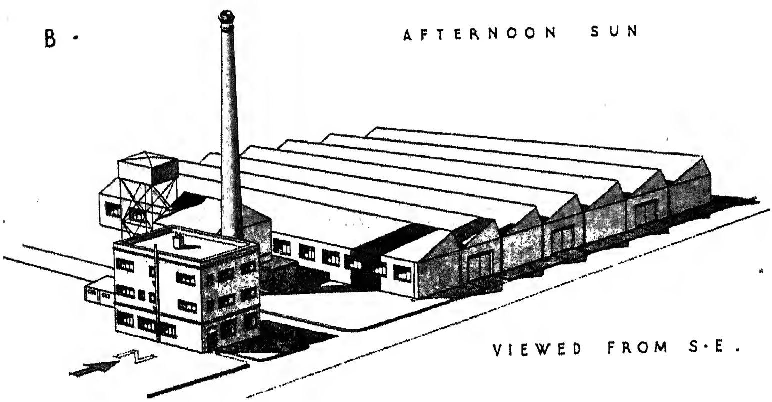


FIG. 251.—Factory oriented N. and S. and viewed from the S.E. under the afternoon sun.

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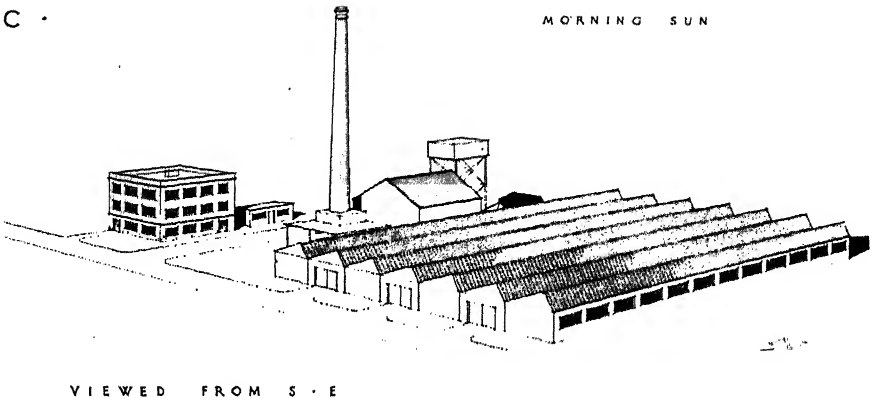

FIG. 252.—Factory oriented E. and W. and viewed from the S.E. in the morning.

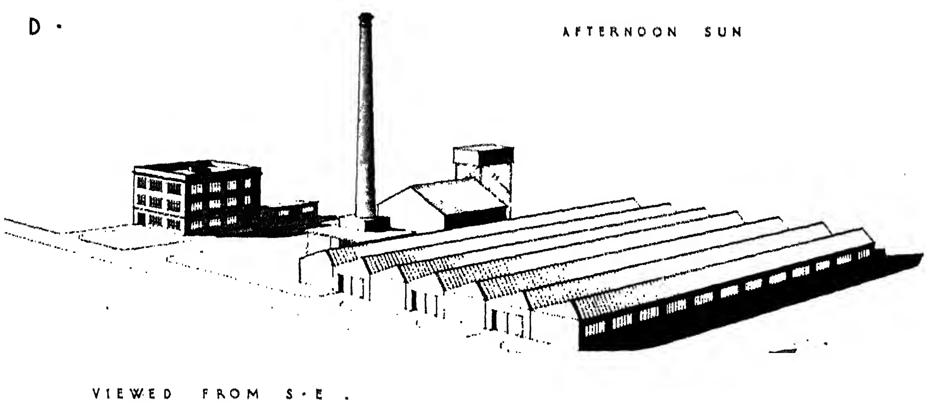

FIG. 253.—Factory oriented E. and W. and viewed from the S.E. in the afternoon.

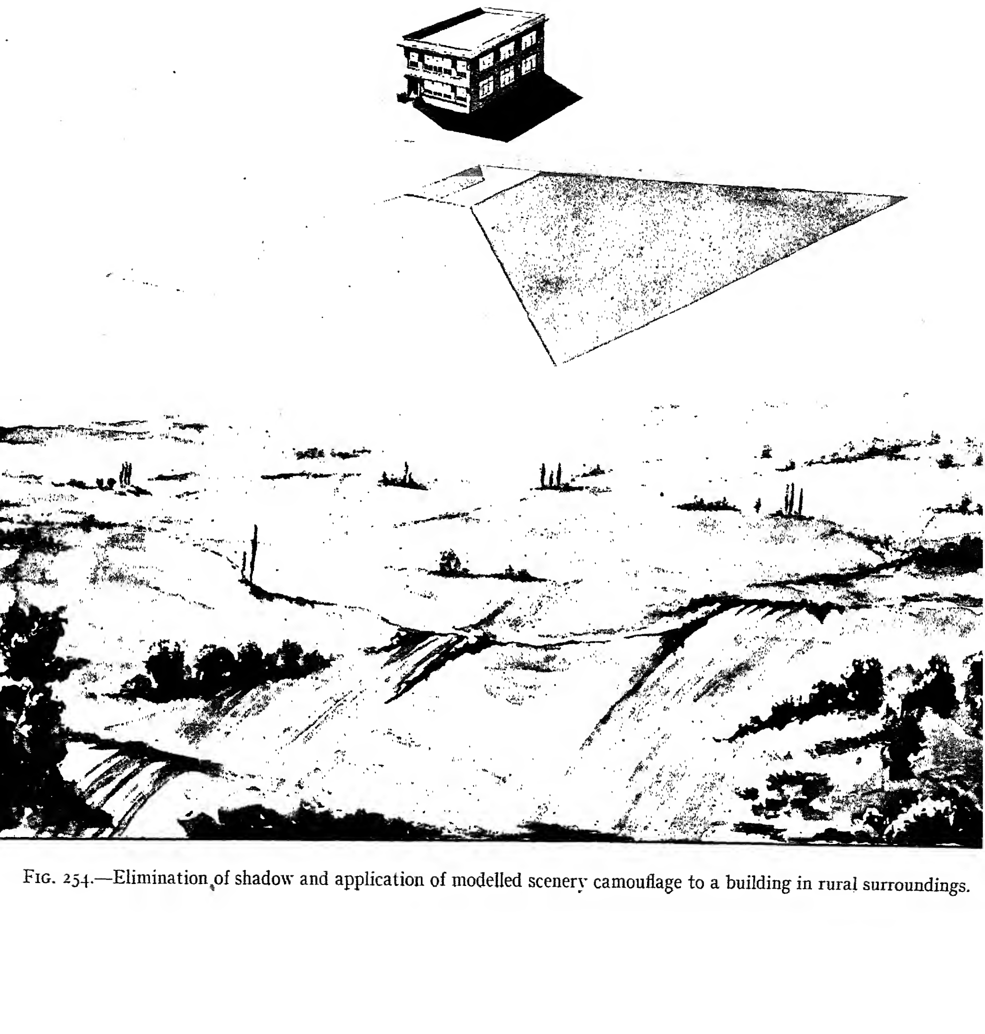

Fig. 254.—Elimination of shadow and application of modelled scenery camouflage to a building in rural surroundings.

angle of between 15 and 30 degrees to the horizontal no shadow will be cast and only by a careful study of the half tones will the actual shape of the erection be detected.

By the use of colour of the right tone and texture the covering can be made to represent the surroundings and the slopes normally of a darker shade brightened up as necessary. The painting of the local features over the structure, with false shadows, completes the camouflage (see the lower illustration). Where buildings are so placed that two walls are never in shadow the shadow elimination methods can be restricted to the other two sides. Care, however, must be taken to break up the sharp shadow under the eaves or cornice.

The method described is an expensive but very effective one which was used extensively by the Germans in the Great War.

Important strategical roads were covered with opaque camouflage upon which the road was painted with side hedges, ditch and shadows complete. Papier-maché excrescences and canvas buildings were also erected where required to complete the effective "solid" camouflage of the countryside, under which considerable military activity was carried on unsuspected and undetected by the aerial observer (see Fig. 248).

An adaptation of the same method of camouflage for hutments or evacuation camps is depicted in Fig. 255.

The top view, A, is a sectional view showing the conspicuous shadows which no amount of painting will disguise. View B shows the complete elimination of shadow by the use of opaque painted camouflage cover arranged with perforations for drainage over roofs and at intervals between.

Disguise of Shadow

Alternative C shows camouflage by the disguise of the shadows by the use of camouflage netting of bright colour arranged to confuse vision through it.

It is a well known phenomenon that a white net curtain hung inside a window will obscure clear vision through to the inside provided the curtain is illuminated from the outside, *i.e.*, so long as the strength of the light outside the window is greater than that inside.

This is the condition which usually obtains in the day time,

but at night when the illumination inside is stronger a white net curtain is unable to obscure vision.

We learn further that as the curtain becomes dirtier or is of a

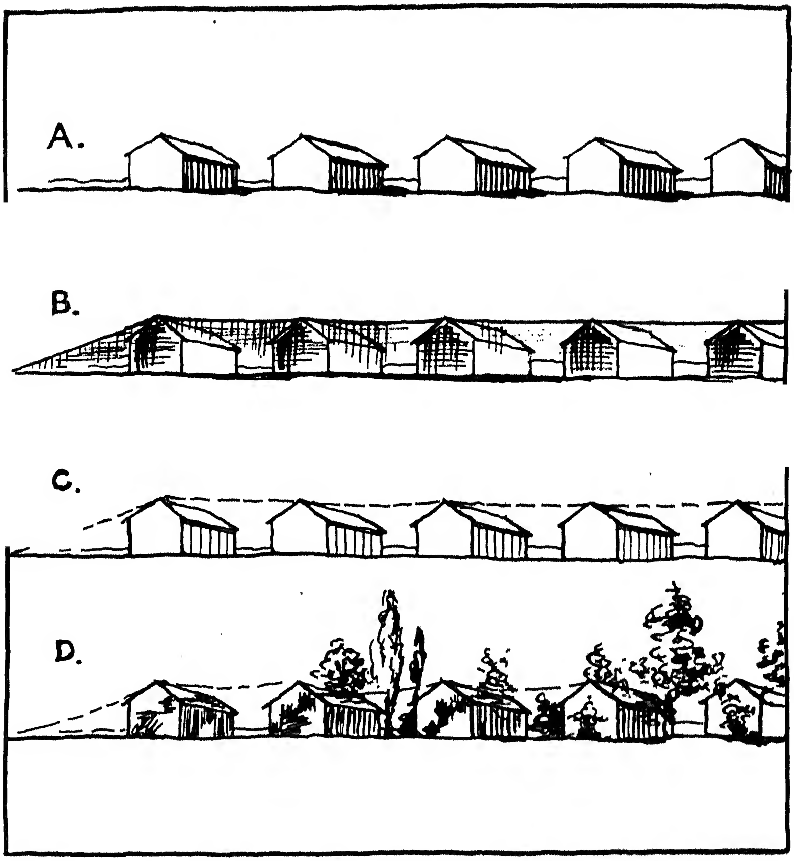

FIG. 255.—Camouflage of hutments.

A. Uncamouflaged.
B. Shadow elimination with opaque camouflaged covering.
C. Shadow disguise by camouflage netting.
D. Camouflage by—
1. Shadow distortion by growing trees.
2. Shadow disguise by netting.
3. Imitative colouration.

darker shade, showing less contrast with the general tone inside the room, the obscuration becomes less effective.

Thus the curtain method of camouflage depends upon bold

contrast and is only effective in daytime or against artificial lighting from the sky, such as from parachute flares at night.

Camouflage netting is often manufactured of hemp or cotton suitably dyed and rot-proofed. Wire netting is also of use provided brightly-coloured strips of cloth are tied thereto, so as to present a brightly contrasting colour with that of the background when viewed from the air.

An advantage of camouflage netting is that it admits daylight and does not present drainage problems.

Where it is a matter of difficulty to use paint, such as where large areas of glass have to be concealed without preventing the admission of light during daytime. Camouflage netting is an advantage.

To cover glass, the mesh when measured on the diamond either way should be not more than ½ in., but the mesh can be larger when non-reflective surfaces have to be covered.

The breaking strain of the net should of course be strong enough to withstand its being pulled taut and to resist the weather.

The Cuprinol process of rot-proofing netting is widely used. This consists of impregnating the fibres with organo-metallic salts, which are sufficiently toxic to prevent rotting. It may be used to colour the nets green or left clear when other colours are required.

Shadow Distortion

The distortion of shadows to shapes that are appropriate to he surroundings is another method of camouflage and D in Fig. 255 shows an application of this principle. In rural surroundings the precision and regularity of the layout of a hutment can be camouflaged by the planting of trees to break the outline of the buildings.

In natural surroundings such trees should be arranged irregularly and netting and colour camouflage introduced where necessary.

In or near plantations the trees must be planted more regularly to preserve the general character of the appearance of the district.

A further example of shadow distortion is shown in Fig. 256, from which it will be seen that the rigid straight-lined shape of

the shadow of the uncamouflaged building is broken up into an irregular shadow simulating those of a group of trees. The work is of a semi-permanent nature, involving the use of irregularly shaped flats of boarding or similar material, fixed to the cornices and raised above the roof in order to throw shadows on the flat roof itself.

Such additions to the building should be at least 6 ft. in least dimension on plan and would also need camouflage by colour.

Shadow Elimination by Counter-shading

The surface contours of an opaque body will be observed to show changes of light and shade by which the artist produces the appearance of relief on flat surfaces.

The camoufleur on the other hand may by careful counter-shading contrive to make a surface in relief look flat, *i.e.*, to give the real the appearance of the unreal.

Fig. 257 shows a cylinder as viewed with lighting from the top left and in front of a background of middle tone and of mottled appearance.

Notice at A the incidence of the light and shade on the curved surface and the gradations from the lightest part on the left to the darkest on the right.

Counter-shading in obliterative paint sprayed on as at B should reverse the tones, *i.e.*, paint of high light-reflecting characteristics should be used in the shadows and darker paint on the high lights.

Viewed as at C, with lighting top left, the object is less conspicuous and looks flat.

The mottled effect, as at D, introduced to match the background completes the camouflage of the object which would only be detected by changed lighting conditions.

Such changed conditions are indicated at E in Fig. 258, which shows the appearance of the camouflaged cylinder when lighted directly from the left. The revised counter-shading is shown at F, which also indicates the proper way of applying the dark colour on the lower portion of the cylinder. It will be seen that this is carried up above the termination of the darker portion of the background and is gradually shaded off to the lighter tone. Viewed under the new lighting conditions it would

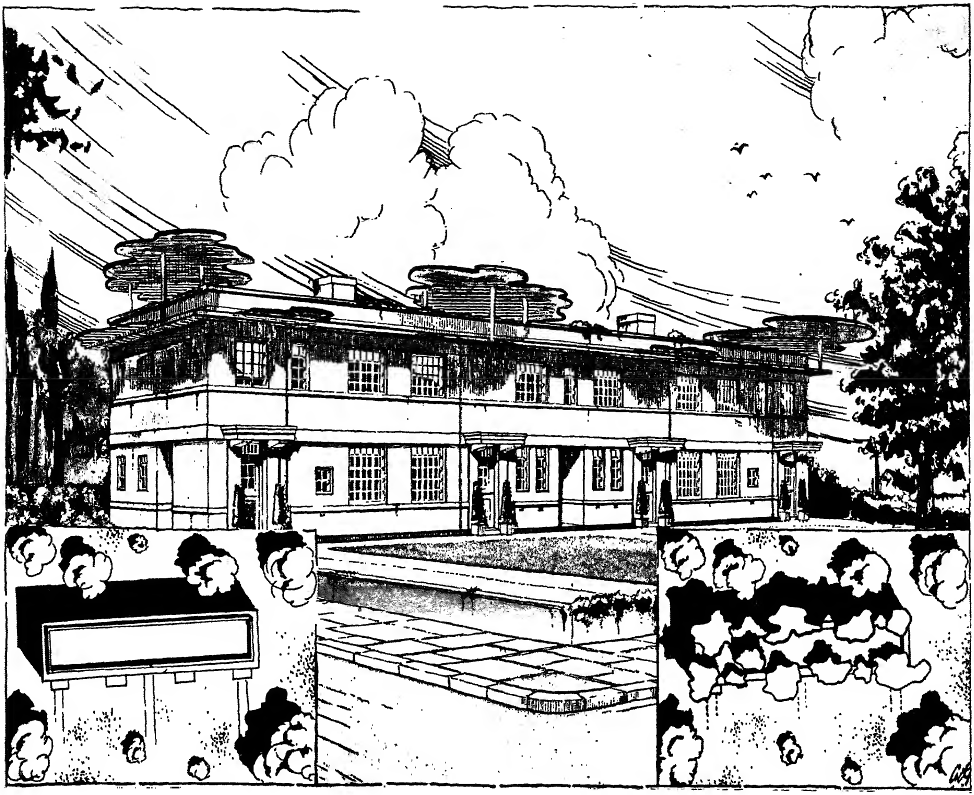

FIG. 256.—Camouflage by shadow distortion. Irregularly shaped additions to building casting shadows simulating those of trees in vicinity. *Left*, uncamouflaged. *Right*, camouflaged.

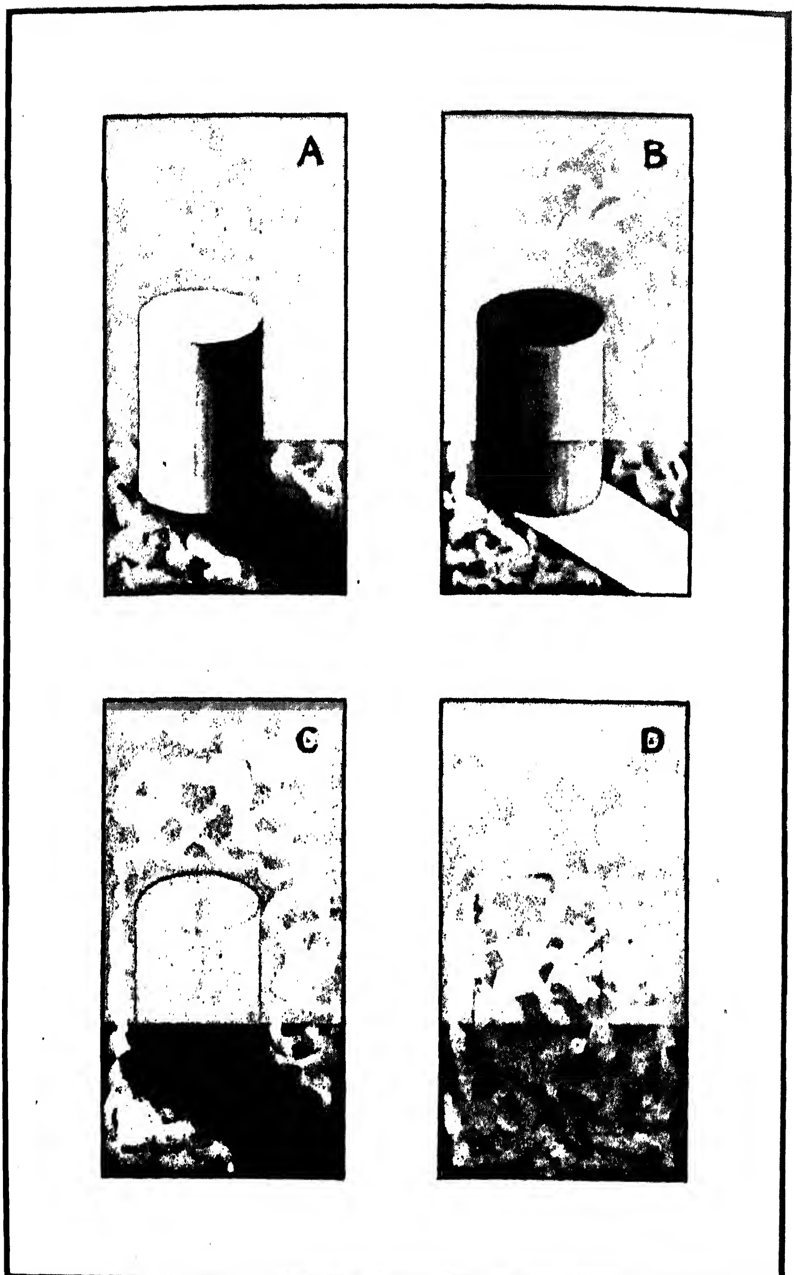

FIG. 257.—Camouflage by countershading.

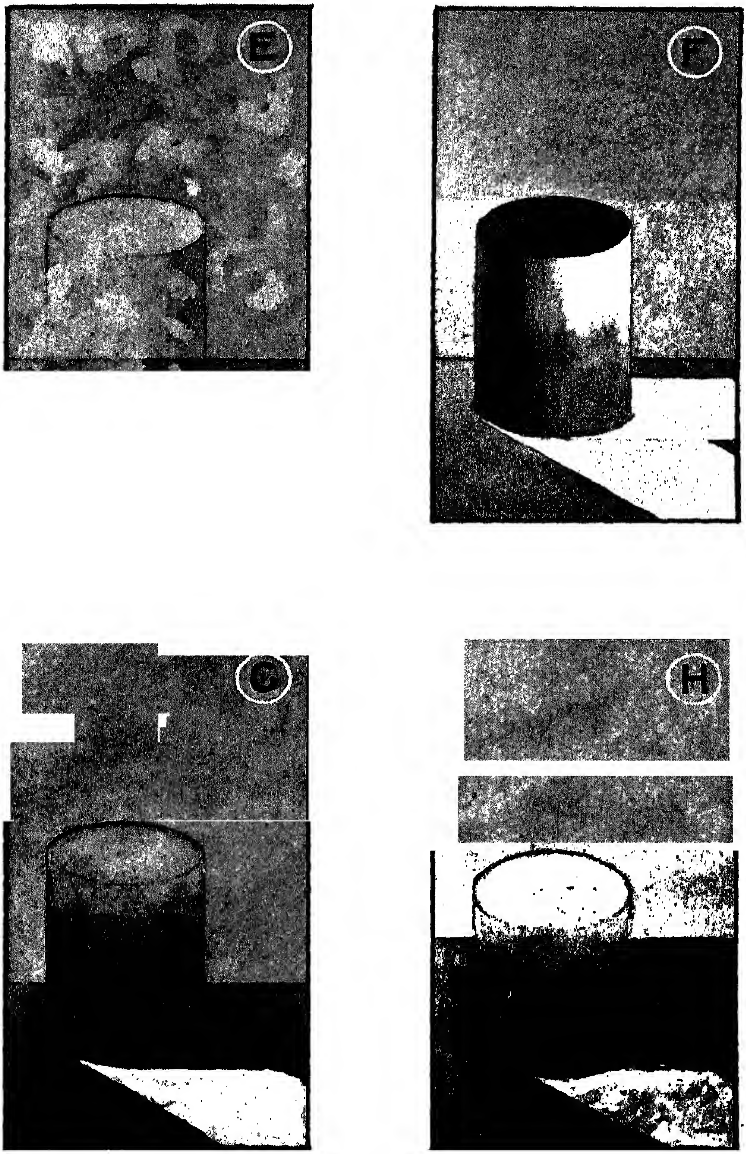

FIG. 258.—Camouflage by countershading.

FIG. 259.—*Above*, Grasshopper inconspicuous on leaf due to harmony of tone and colour as seen in ordinary panchromatic photograph. *Below*, Conspicuous on the leaf in an infra-red photograph.

(Courtesy Dr. Hugh B. Cott, The Royal Engineers Institute and The Photographic Journal.)

To face page 567.

present the appearance generally as shown on G, which is perhaps not so indistinguishable as case D, but which is never-less inconspicuous.

The camouflage does however serve for the two positions of the lighting and also for a more vertical view as shown at H. Here, of course, the top of the cylinder viewed more normal to its surface shows a high degree of reflection of light and therefore presents a lighter tone. The cylinder is, however, still quite inconspicuous and the camouflage is still quite effective.

Colour

The analysis of sunlight dispersion due to refraction when the light is passed through a prism produces the colours of the rainbow called the spectrum. The order in which the colours appear is as follows : Red, orange, yellow, green, blue, indigo and violet ; the red end is deviated less and the violet more than the yellow light which appears in its original position. The fundamental observations are due to the illustrious Newton who experimented with sunlight which passed through a small slit in the side of a darkened room. He showed that what was called white light is composed of the colours of the rainbow and that certain materials which have the property of absorbing certain parts of the spectral colours which fall upon it, reflect only the remainder and thus exhibit what is now regarded as their characteristic colour. Thus a surface which reflects the red part of the spectrum would exhibit a red colour, and such a surface may be caused to change colour when viewed in white light by the application of some other surface such as paint which has different light-reflecting characteristics. For example, a green paint absorbs all the spectral colours except the green, which is reflected, thus exhibiting this characteristic colour.

Any coloured surface possesses three principal qualities—*colour*, *tone* and *texture*.

Colour bears its usual meaning as described above but *tone* is judged by the amount of light reflected by the colour and is expressed as light or dark, depending upon the amount of light reflected. There is no simple standard of measurement for tone but the term is a comparative statement of the strength of the light reflected from the surface. Thus one speaks of a light

tone or a dark tone, intermediate values being classified purely by comparison. Tone variations are spoken of as differences in light and shade and have no bearing upon differences in colour. That is to say a light red may have the same tone value as a dark red although the latter will contain less of the yellow end of the spectrum and more of the blue in its make-up.

The visibility of objects depends not upon any inherent virtue of their own apart from bodies which are self luminous, such as those which are phosphorescent or which are fluorescent, but upon the amount of light which they reflect. Objects therefore do not possess the property of making their own colours but the colour which is observed is due solely to the unabsorbed light which is scattered and reflected from the surface. The same object having definite reflecting characteristics and viewed under different qualities of incident light will appear to have a different colour. Thus a red object seen under blue light would absorb the whole of the light falling upon it and would appear to be black and it is solely on account of this phenomenon that photographs utilising the infra-red part of the spectrum have disclosed objects which were normally invisible. Fig. 259 illustrates this in a striking manner; the grasshopper is not visible on the leaf upon which it is resting owing to harmony in colour and tone when photographed with the ordinary panchromatic plate. In the infra-red photograph, however, the differentiation between the insect and its surroundings is clearly brought out. This is due to the fact that the chlorophyll of leaves reflects light in the infra-red region of the spectrum and therefore appears white in the infra-red photograph. Small green animals which live upon the foliage differ greatly in their absorption of infra-red light and produce the phenomenon referred to.

Texture is the quality of a surface—rough or smooth—matt or glossy—which determines the amount of incident light which is dissipated by diffusion; thus a matt surface which scatters light in all directions appears darker than a smooth surface of the same colour and tone. A glossy paint behaves according to the laws of specular reflection and in certain circumstances may have a reflecting coefficient as high as that of an ordinary mirror.

Ordinary flat paint reflects less light than a glossy paint but

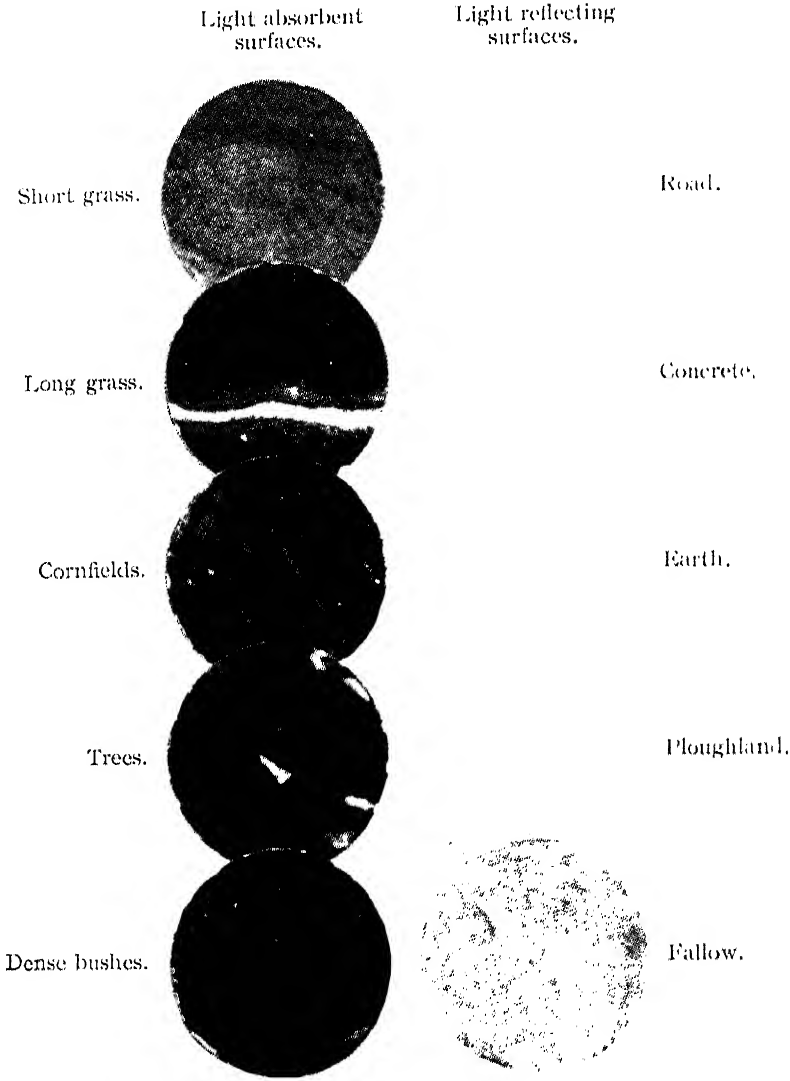

FIG. 260.—Showing relative tone values in the landscape.

Note.—The above illustrations are from photographs taken in the dry weather. After rain the tones would generally be deeper, but some highlights might be reflected from very wet surfaces.

(*Courtesy The Silicate Paint Co. Ltd.*)

[*To face page* 560.

is still much too reflective when viewed at low angles of vision. For this reason it is necessary to add solid articles to the paint in order to roughen the finished surface.

Variations of light intensity under which an object is observed have an effect upon its visibility since the contrast between the high lights and the shadows is increased at high intensities of illumination. In the latitudes of southern England there is an increase of illumination at midday during June and July of something over 40 per cent. compared with midday light of the winter months. Apart from this, atmospheric haze has an influence upon the visibility of objects seen from the air and this affects both visual observation and photographic records.

The effects of haze upon contrast are not the same visually and photographically and tests carried out in America have shown that large coloured canvases photographically non-selective in reflection gave the respective reflecting powers as shown in the table below.

TABLE CV

Canvas	Reflecting Power	
	Photographic	Visual
White . .	56·0	64·8
Grey . .	17·5	20·1
Black . .	6·7	7·5

In camouflage for civil defence purposes it is fortunately not essential to defeat the camera since the primary object is to prevent the bomb aimers' recognition of the target by visual observation.

Panchromatic plates or films used in aerial photography are the most efficient in meeting all the exacting requirements and afford crisp contrast and excellent definition. The panchromatic emulsion is sensitive to all colours of the spectrum and in addition it possesses dominating sensitiveness to red. By the use of such a plate combined with an orange filter the aerial photographer can obtain a distinct photograph with good

contrasts under atmospheric conditions such as when the eye can see very little and features not normally noticed are clearly brought out in such photographs.

The relative actinic values of various types of landscapes are shown in Fig. 260; fields, trees and smaller foliage are chiefly conspicuous; they vary very slightly in colour tone and reflect but little light. The contrast between them is therefore not marked and they are distinguished only in relation to more reflective objects near them.

Waterways give striking light values when reflecting the rays of light from the sun, moon or the stars, but in certain circumstances as when viewed from the direction of illumination and not opposite to it they afford but little illumination. Pure water which transmits all the colours of the spectrum with equal facility is regarded as colourless but large volumes of such water from the photographic point of view may at times be distinctly coloured, and appear blue or green according to the relative positions of the sun and the observer.

The light shade values of colours are by no means relative to that of natural or manufactured materials, thus a green paint which exactly matches the green leaves of trees if applied in a large flat surface will not simulate the appearance of trees which have a very high proportion of shadow in their general appearance.

Visual appearance of landscape and a panchromatic photograph of it are sufficiently alike to justify the extensive use of photographs in the preparation of camouflage schemes.

The attention of the reader is directed to the difference in tone between the appearance of earth and short grass. Although the earth may normally be of a very dark colour it absorbs very little light and so produces a light photographic tone.

Ground Pictures

Ground pictures for the purpose of deceiving the observer can often be made by removing a patch of turf the shape and size of one side of a pent house roof which would show up nearly white, and allowing the grass to grow long in a patch the shape and size of the other side of the roof produces a shadow effect. Such expedients may well serve to confuse the

casual observer in the air, and where this is desirable such deceiving ground pictures can be maintained over a long period.

In the latitudes of this country of course such imitation shadows should be placed to the north side of the denuded patch and they will then appear sufficiently logical for the greater part of the day.

Approved shades of camouflage colours are shown in Fig. 261, on which it will be seen that very bright colours are not normally recommended.* These latter are only to be used in special cases where disruptive colouration and dazzle is aimed at. In no circumstances should glossy surfaces or varnished treatment be employed.

Patterns should also be extremely bold and in no cases less than 6 ft. in dimension.

Roofs should always be painted darker than walls since roof surfaces take the sunlight more directly and reflection from them is very much greater.

When matching colours it is well to remember that the colour on a small sample card will look lighter when applied to a large area. It is obvious of course that fast colours should be used and a rough surface which becomes shiny on being subjected to a shower of rain should be avoided.

Paints

Normally the function of an outdoor paint is to act as a preservative form of decoration to prevent deterioration by the weather and to provide an elastic and durable waterproof skin over the surface of the object painted. The paint consists of a pigment and a vehicle for binding the pigment to the surface and a thinner to enable the paint to be spread. Fillers and dryers are also added to give the paint a body and to assist in its hardening.

The constituents of paint are carefully balanced to achieve the maximum durability and the durability and elasticity is usually afforded by the use of a full proportion of an oil medium or vehicle. Such paints produce a glossy finish and are not suitable for camouflage purposes. Matt surfaces are, however, produced by increasing the proportion of pigments or diluents and this results in a reduction in the durability and elasticity

* It is regretted that official permission to reproduce Plate 261 is not forthcoming in the National Emergency.

of the covering. In many cases camouflage paint is not required as a preservative, such as when used on asbestos, cement or brickwork or concrete or where preservative coats of paint already exist.

In these cases the essential requirements of the camouflage materials are colour fastness and sufficient durability to avoid frequent renewal. Cheapness and large covering capacity are also desirable.

Types of Paint and their Properties

A. *Oil Paints.* In these paints the binding medium is an oil which may be used with or without the addition of varnish, gums or resins. Linseed oil is most generally used and for external work the boiled linseed oil is used to give the most durable paint surface. When new, oil paints produce a glossy surface, but this tends to disappear after exposure.

As already pointed out initial mattness can be produced by increasing the pigments and fillers but only at the expense of elasticity and durability of the paint film.

Gritty grades of oil paint are made by the incorporation of gritty particles in the body of the paint during manufacture; the surface thus produced has an excellent texture and is truly matt. If the particles are sufficiently small (pass 20 mesh) the paint can be sprayed in a special gun. The covering capacities are approximately as below.

Gritty grades. 10–15 sq. yds. per gallon on absorbent surfaces.
15–18 sq. yds. per gallon on non-absorbent surfaces (like glass).

Non-gritty matt grades. 35–40 sq. yds. per gallon on absorbent surfaces.
55–60 sq. yds. per gallon on non-absorbent surfaces.

B. *Oil-bound Distemper.* These are water paints in which the binder consists of an emulsified drying oil and/or varnish. They are usually supplied in paste form ready for thinning with water. They can be applied by brush or sprayed and are suitable for application on glass, new or old concrete, new or old brickwork, tiles, asbestos roofing, etc. They are com-

paratively cheap and are suitable for many camouflage purposes. Covering capacities per coat are approximately as below.

Gritty grades. 60–80 sq. yds. per cwt. on absorbent surfaces.

150–175 sq. yds. per cwt. on non-absorbent surfaces.

Non-gritty grades. 150–175 sq. yds. per cwt. on absorbent surfaces.

350–400 sq. yds. per cwt. on non-absorbent surfaces.

C. *Bituminous paint* in which the binder is bitumen in solution or in emulsion.

These are very durable paints and the colours are dull and cover most of the range required in camouflage. Their characteristics are similar to those of oil-bound water paints, the covering capacity is about the same. They are specially suitable for use on new concrete and asbestos cement, on which the alkalinity is usually destructive of the ordinary oil paint.

D. *Silicate paints*, in which the binder is sodium or potassium silicate.

These are best suited for use on porous surfaces and offer good resistance to the weather. Their covering capacity is intermediate between that of oil paint and distempers and they can be applied by brush or spray.

E. *Cement paints*, in which the binder is portland cement.

These are best suited for use on porous surfaces and considerable care is required in the selection of the pigment, as these paints are apt to show patches due to efflorescence after exposure to the weather. In all cases a paint which maintains its non-reflecting characteristics even after a shower of rain should be used in preference to those which shine in such circumstances. The covering capacities for cement paints are approximately as below.

100–120 sq. yds. per cwt. on moderately absorbent surfaces.

F. A number of *proprietary paints* producing a coloured rough stone-like surface and in which are used special binders like rubber latex are available. These are very durable and are particularly suited to use in camouflage work; they normally do not shine when wetted.

The Painting of Various Materials

Wood, corrugated iron, steel or similar non-absorbent smooth surfaces. All the above mentioned paints would be suitable, but oil or bituminous paints are most durable as they maintain their elastic properties and do not tend to flake off.

Asbestos Cement and New Concrete. These surfaces slowly produce free lime and their alkalinity is destructive to oil-bound paint, unless a petrifying solution is first applied or bituminous or special alkali-resisting paint is used.

The difficulty in painting cement or concrete walls and other surfaces is due to the fact that portland cement, during the action of setting, undergoes a change which results in the liberation of calcium hydrate, the solution of which salt has a very destructive action upon colouring matters of an organic nature and even upon many of the mineral pigments used in the manufacture of paints.

The liberated calcium hydrate also saponifies the linseed or other vegetable oil employed as a vehicle for the pigment, gradually converting the oil into soap and thereby rendering it soft and easily removed from the surface of the cement wall by abrasion or weathering. When the surface has become thoroughly indurated the calcium hydrate has become carbonated to a considerable extent and in this condition it is inert and has no deleterious effects upon paint applied to the surface.

A number of methods for dealing with this defect have been tried but a wash of zinc sulphate gives satisfactory results.

Forty-eight hours after the rendering has been complete or the concrete has set, the surface should be washed over with a 50 per cent. solution of zinc sulphate and water, allowing forty-eight hours or more for this to dry; the paint should then be applied in the ordinary way.

The combination of the zinc sulphate with the calcium hydrate forms zinc hydroxide and calcium sulphate which fills the surface pores of the concrete and neither of which have any deleterious effects upon colours commonly used in paints.

Slates, Bricks and Stone Walls. All the types of paint above-mentioned are suitable, but it is desirable to use an alkali-resisting priming when oil paint is used on concrete or where it is likely to be effected by lime mortar in masonry joints.

Asphalte. A bituminous paint is best for use on asphalte surfaces as the "bleeding" from an underlying bituminous coat usually spoils any other surfaces.

Concrete Roads and Paved Areas. Paints applied to these surfaces are subjected to severe weathering conditions as well as wear and tear and the durability is dependent upon the binder employed. Bituminous emulsions fulfil the conditions most nearly although all other types of paint can be used. Experiments are being carried out on the painting of concrete roads and the use of stains of various kinds. Sprayed paints of a cellulose base are far too expensive, whereas the water-bound paints only last a few weeks. A stain which permeates the surface is likely to be the most satisfactory.

Glass

All roof glass requires treatment to prevent the shine which can be seen from great distances. Even north lights require treatment as the early morning or the evening sun is usually reflected from them. Roof glass can be stippled with the same paint which is used for the roof covering or, alternatively, the windows can be covered with a clear varnish and then sprayed lightly with granite or similar dust which will pass a 20 mesh sieve. Natural sand is not recommended as the individual particles themselves shine. If it is desired to continue the roof pattern over the windows, appropriately coloured particles should be used, and it will be found that adequate protection from shine can be obtained without cutting off more than 50 per cent. of light.

It will be appreciated however that this subject must be dealt with in conjunction with the question of the obscuration of artificial light, and when it is realised that nearby bursts of bombs will most certainly break most roof glazing in factories the treatment of the glass itself can only be regarded as a temporary measure.

Other methods of light obscuration exterior to the building in which camouflage schemes can be embodied should, therefore, be considered when dealing with a permanent solution to this question.

Roofs

All roofs should be painted with dark colours since the reflection from roof surfaces is greater than from vertical surfaces, when viewed from the air. Ordinary matt paints are not sufficiently dull to prevent serious reflection and gritty particles must therefore be added. An aternative method is to spray the roof with a coat of varnish, upon which coloured particles are spread. The texture is excellent and the durability good if high quality varnish or coloured emulsion is used. Local grit, such as brick dust, ground slag, etc., can be scattered over a roof surface previously treated with a bituminous binder, provided the particles are not larger than $\frac{1}{8}$ in. in order to secure good adhesion.

Ordinary sanded bituminous flats will often require spray painting to produce the desired camouflage effect.

Flying Fields

In the camouflage of flying fields the grass is usually cut short, then sprayed with a weak solution of a weed killer and sprayed over with a paint which produces in plan view the original ditches and hedges which crossed the field. This, of course, requires replacement periodically owing to the growth of the grass.

Galvanised Corrugated Iron

New galvanised corrugated iron, which is now being used on a large scale for factory extensions and roofing generally, reacts chemically with paint and it is necessary to render the surface inert in order to prevent the paint peeling off. Special undercoatings are now obtainable and these should be applied prior to the application of the protecting medium.

Disruptive Colouration

We have seen that the judicious use of counter-shading may do much to render an object inconspicuous when seen from the air, but it will readily be appreciated that it is very difficult completely to satisfy all requirements under changing conditions, such as different angles of vision, different degrees of lighting and different orientation of the object to be camouflaged.

Counter-shading may enable surface contours to be camouflaged, giving the object a flat aspect but the variation in light which falls upon the whole aerial view at times would cause such an object to stand out more or less conspicuously against lighter or darker or differently coloured surroundings. By the application of optical principles involving the use of patterns, effective concealment may be obtained by the obliteration of the bounding contours or tell-tale form.

If an object is covered with irregular patterns of contrasting colours and tones they catch the eye of the observer whose attention is distracted from the underlying form of the object so covered. If it is not possible for the pattern applied completely to blend with the picture of the neighbourhood the patterns should be made conspicuous enough to contradict the form upon which they are superimposed. The functions of the disruptive patterns are to prevent or delay as long as possible the first recognition of the object and the patterns should therefore be of boldly contrasting colours and may even be glaringly conspicuous. It is important to ensure that those parts of the pattern which are conspicuous should be shaped so that their real identity could only be determined with difficulty.

The effect of a disruptive pattern is greatly strengthened if some of the colours of which it is composed, closely resemble the background, whilst others differ strongly from it.

Fig. 262, which is taken by permission from the *Royal Engineer's Journal,* illustrates the principle and shows a series of simple forms—fish, an egg and a moth—shown firstly as self-coloured objects of a more or less uniform tone and which are easily recognisable, and in other cases covered with disruptive patterns viewed against different kinds of background.

In the second series of illustrations it will be seen that the colours used in the disruptive pattern all contrast with the background and the obliteration of the outline is incomplete. In the last two examples, however, where one of the colours used in the disruptive pattern matches the background the complete outline of the objects camouflaged is lost.

In applying the principles of disruptive colouration in the camouflage of objects presenting a definite characteristic

outline, it must therefore be the endeavour to make some of the colours used in the disruptive pattern merge with the background, especially where the pattern joins the outline of the object.

The use of strongly contrasted tones in the make-up of a disruptive pattern greatly increases the illusionary appearance, as will be seen from the illustrations in Fig. 263. The first

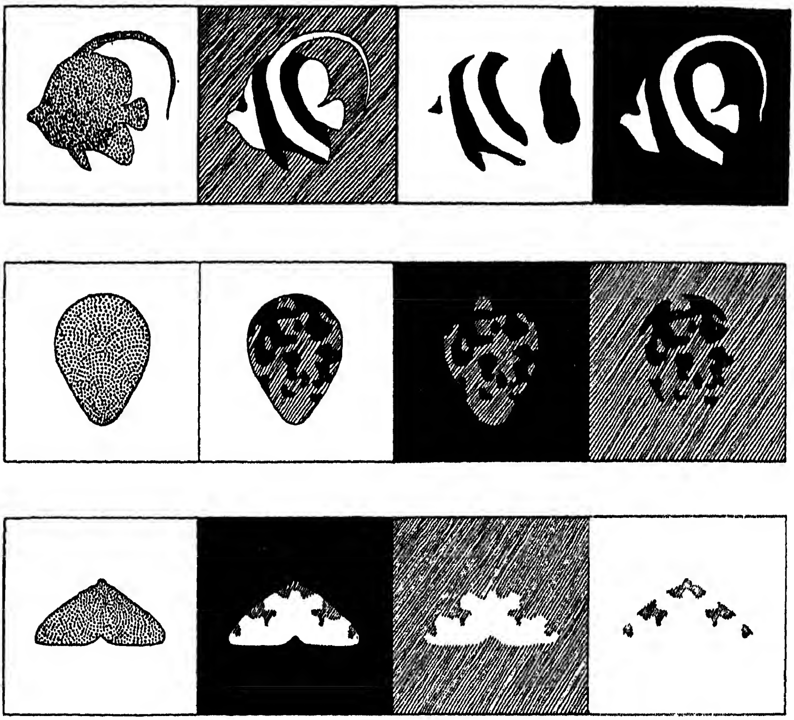

FIG. 262.—Fish, egg and moth with disruptive colouration viewed against different backgrounds.

(Courtesy R. E. Journal.)

illustration shows the disc coloured with a uniform tone and the form is therefore clearly distinguishable against the white background of the paper. The second illustration shows a disruptive pattern applied to the disc confusing somewhat the general appearance of the outline.

In the third illustration the edge contrast on the disruptive patterning is increased by the introduction of a white strip

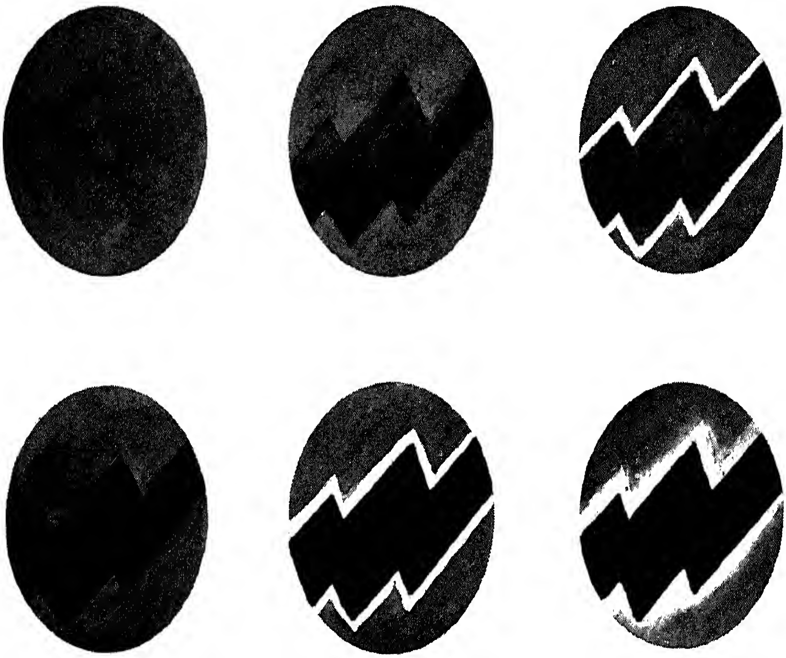

FIG. 263.—Camouflage by disruptive patterning showing advantage of contrast.

[*To face page* 578.

dividing the darker irregular shape from the grey background of the disc. It will be seen that the increase in contrast in adjacent colours in the disruptive pattern increases the illusionary appearance. The same may be said of the fourth illustration by which a similar effect is obtained through the darkening of the edge of the disruptive pattern itself.

The fifth illustration shows a combination of the two methods, and the last the introduction of differential blendings and tones away from the sharp edges of the disguising pattern. The use of disruptive patterning such as this is invaluable for the camouflage of large objects such as ships, tanks, gasholders,

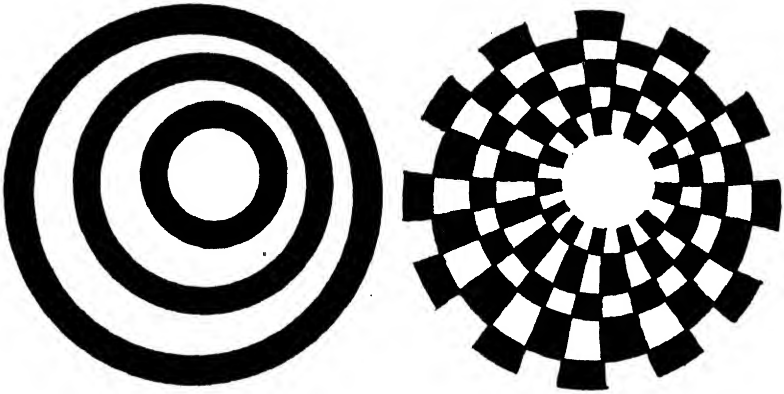

FIG. 264.—Dazzle painting. A. Pattern coinciding with outline emphasises the latter. B. Pattern interrupted at contour confuses outline.

buildings, etc., but this form of camouflage must be applied with vigour and in bold outline with strongly contrasting tones adjacent to each other.

Disruptive colouration may be used for—

(*a*) *Disguise of surface* by the optical destruction of what is present as already described.

(*b*) *Disguise of surface* by the use of coincident patterning by which structurally disunited parts are optically joined, as in the case of many frogs who carry glaringly conspicuous patterning on the body, carried right across the legs, uniting the pattern into one whole outline when the animal is in the normal posture of rest.

Such united patterns to be effective in concealment must

present an appearance completely different from the form camouflaged but not incongruous in the surroundings.

(*c*) *Outline obliteration* by means of interrupted patterning at or near the margin. An illustration of the method is given in Fig. 264, which shows a white disc painted with disruptive colouration or dazzle camouflage.

In the left-hand figure it will be seen that the pattern coin-

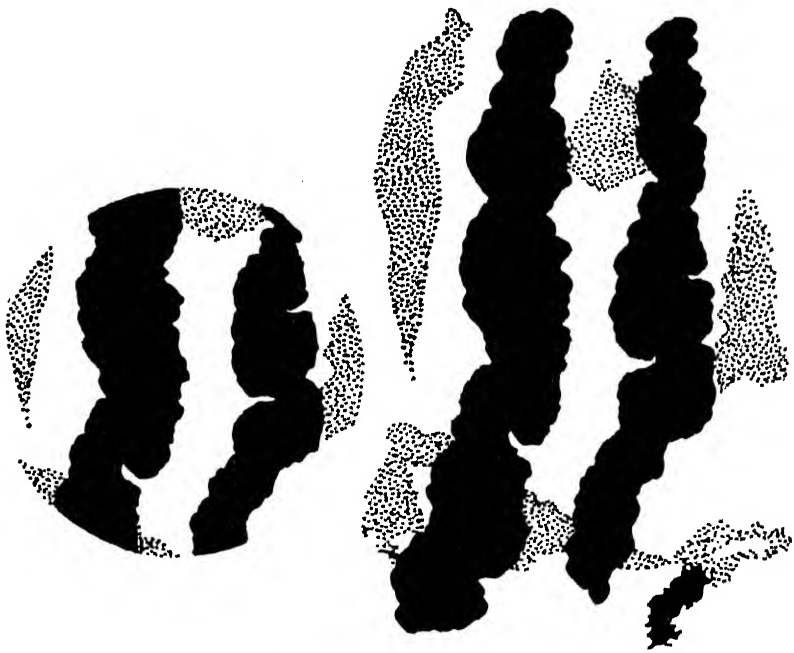

FIG. 265.—Dazzle painting.
A. White disc with disruptive patterning.
B. Disc with dazzle painting matching background.

cides with and therefore emphasises the outline of the disc, but in the right-hand figure the marginal pattern is interrupted at the outline which gives an optical illusion and obliterates the true outline.

The differences between the two treatments can be observed better at a distance.

The scale of the pattern requires special consideration as it must be sufficiently large to be clearly discernible from the distances at which the camouflage is required to be effective.

The departure from repetition and geometrical symmetry in the design, as shown on the left-hand side of Fig. 265, improves the concealment of the shape of the object and in the case of stationary objects like tanks and buildings, the merging of the pattern into that of the surroundings greatly increases the deception (see right-hand side of Fig. 265). Such realistic scenic treatment is invaluable in camouflage of fixed objects, as not only is the form of the object broken up optically into a number of patches of contrasting tones but the shapes and tones of the patterns, harmonising with those of the surroundings, render the camouflaged object unrecognisable.

Imitation

An aerial observer in a plane some 10,000 ft. high obtains a convenient view of any particular spot on the landscape for a longer period than is possible when travelling at a lower altitude, when the speed of the aircraft has a greater influence upon the view.

At worst he may obtain but a fleeting glance and at best he sees only the general pattern of the landscape.

It is not necessary therefore to make an exact copy of the surroundings in detail but to ensure that the general picture of the character of the neighbourhood is maintained. Fig. 266 shows at the top the appearance of a factory from the air and illustrates the difference between the reflecting characteristics of matt and glossy paint of the same colour and tone.

The right-hand top view shows the " deep furrows " appearance of the uncamouflaged north light roof, showing deep, clearly defined shadows on the north side. When such buildings are not exactly oriented the morning or evening sun and strong moonlight produce an occasional tell-tale glint from north light glazing.

The best method of dealing with both of these defects is to use dazzlingly contrasting camouflage netting festooned from ridge to ridge as shown in the fourth view in the figure.

The third view shows the factory painted to imitate urban surroundings with the road " carried through " the premises by appropriate painting on the roof.

The last two illustrations show camouflage by imitation of rural surroundings.

In order to prevent the unnatural appearance caused by the breaks in the roofs when the " road " passing across the roof is viewed from different angles the sides of a road or stream thus painted must be edged with painted trees or large hedges, the irregularities in which can be arranged to cover the breaks referred to.

Practice

In preparing a camouflage scheme it is essential to form a picture of the neighbourhood, into which the scheme is to be fitted. This can be done by

(*a*) Flying over the site.

(*b*) Taking aerial photographs of it, preferably from the four cardinal points of the compass, when the shadows are long—morning and/or evening. The photographs should be obliques.

(*c*) Making a model of the establishment and the immediate surroundings—a convenient scale is 1–200, and a suitable type of model is shown in Fig. 299.

(*d*) Studying the map of the locality.

It is convenient to mount the model on a turntable which can be tilted, thus enabling any desired lighting and angle of view to be obtained.

In this way camouflage schemes can be tried out in colour on the model and much experimental work and waste of time and material on the work itself can be avoided.

Urban Areas

The general impression of an urban area as seen from the air is usually a chequered pattern of houses, gardens in more or less regular areas, roads and a few open spaces.

The colours presented by the view will be *dazzling white* from skylights, greenhouses or water (in some angles of view).

Grey from roads darkened at places by traffic and pedestrians, slate roofs in two principal shades, and some gardens.

Brick red from some walls and roofs.

Yellow from some brick walls and gardens.

Brown in various shades from earth.

Brown green from grass and gardens.

All *shadows* being in *dark colours* or *black*.

FIG. 266.

A. Showing difference between matt and glossy surfaces.
B. Imitation of urban surroundings.
C. Camouflage to match rural location.
D. The marked appearance of N. light roofs.
E. The same camouflaged with dazzle nets.
F. Nets and painting to imitate rural surroundings.

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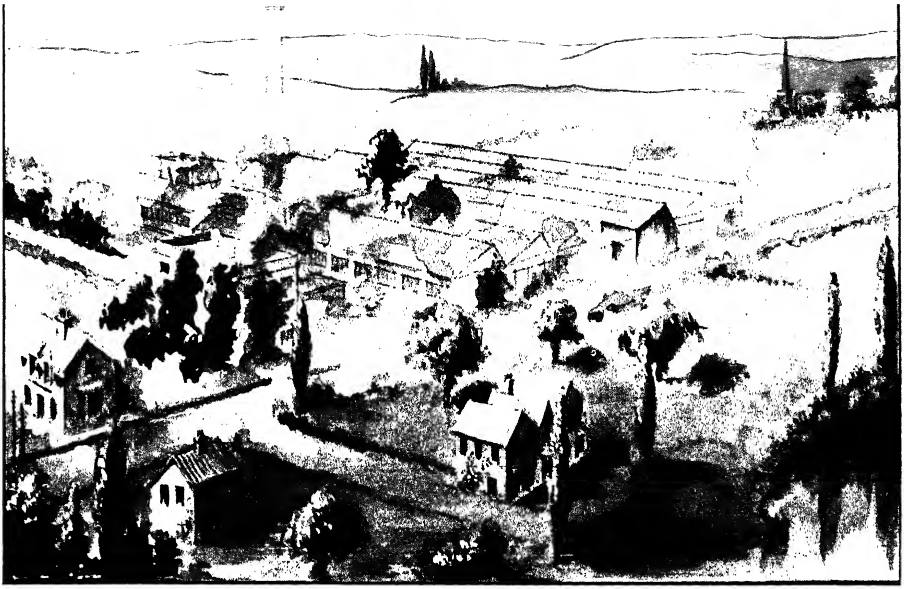


FIG. 267.—Camouflage of factory shown in Fig. 251 to simulate rural surroundings.

The general tone of an urban area seen from the air will be somewhat dark.

In effecting the camouflage it will be necessary to—

(1) Darken all light surfaces to conform to the prevailing tone of the neighbourhood.

(2) Treat all roof lights to prevent shine.

(3) Darken all light concrete roads not required to be conspicuous in the final picture.

(4) Obliterate unwanted shadow by one or other of the methods described in this chapter.

(5) Destroy the succession of symmetrical shadows or expansive roof surfaces by imitative or disruptive patterning.

(6) Employ counter-shading when required to flatten out relief or to lighten up hard shadows.

(7) Employ natural breaks, such as growing trees, or creeping plants wherever possible in preference to paint.

Rural Areas

The oblique aerial view of a rural area usually presents a broad expanse of fields showing a patchwork appearance of varying tones (see Fig. 267), hedges with deep shadows, trees and woods, winding roads, streams, scattered houses and perhaps a village.

The marks of the plough are clearly seen, and the difference in tone due to condition of crops or surface of fields is more marked than light and shade due to topographic contours.

The methods of approach to the problem of camouflaging an establishment in the country are similar to those set out on p. 582, but in rural areas it is more than ever necessary to avoid uniformity in the treatment of the camouflage.

The judicious planting of trees and shrubs is particularly useful in the disguise of a large industrial establishment in a semi-rural area and has the advantage of naturalness and permanence.

Camouflage in the Future

There is no doubt that the necessity for concealment from the air dictated by the established principles of defence will influence the choice of materials in the design and construction

of large and important industrial establishments in the future.

Roof lights which reflect light from the sun and moon and which are particularly vulnerable to damage by blast, splinters and shell fragments are likely to be superseded by solid glass bulls-eyes or prisms, which are embedded in flat reinforced concrete roofs.

Where continuous patent glazing is desired this may with advantage be of the form shown in Fig. 268.

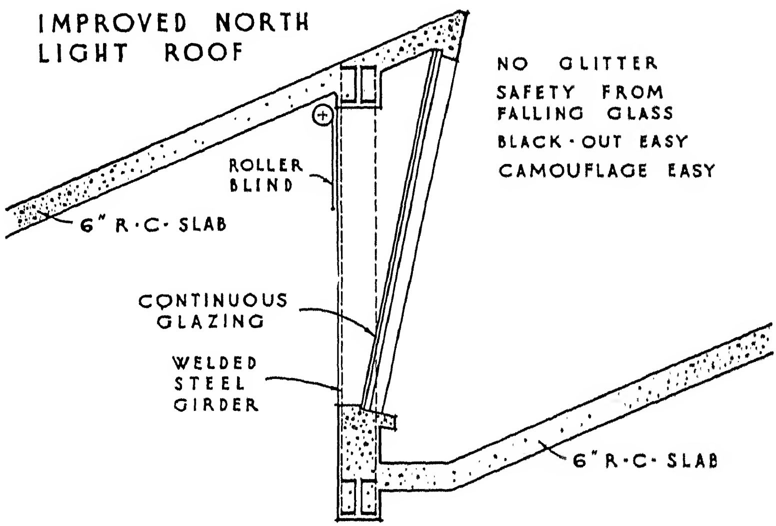


FIG. 268.—Improved North light complying with Civil Defence principles.

The fact that the glass leans outwards at the top has the following advantages :—

(1) It is not possible to see a glittering reflection from it in the air.
(2) Its camouflage is therefore easier.
(3) Fractured glass would be caught safely on the exterior of the roof.
(4) Blacking out by means of interior opaque roller blinds is facilitated.

Roofs. For economy, permanence, protection against the incendiary bomb and ease of camouflage the roof of the future

might well be as shown on Fig. 269. The concrete roof carrying 3 ft. of earth makes possible the growing of crops on the roof, thus recovering to agriculture some of the lost acreage, providing automatic camouflage, protection against the incendiary bomb and increased thermal insulation.

The sloping sides eliminate shadow and provide storage

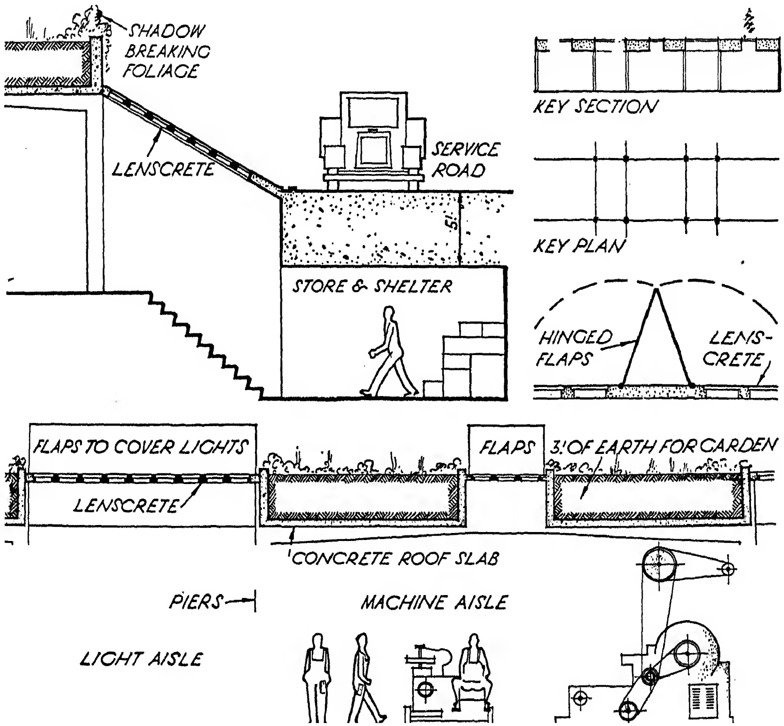


FIG. 269.—The factory of the future.

space or cover to the store-shelters, giving class 6 protection exterior to the building.

For blacking out and for camouflage of the Lenscrete roof lights the use of folding flaps as indicated would be found advantageous.

Walls. In buildings of tactical importance exterior walls as such should not be free-standing but should be replaced by the shadowless roof slope indicated on the figure.

Building Materials

There is no reason why manufactured building materials, like asbestos cement, protected metallic sheeting, roofing felts, tiles, bricks, etc., should not be made of colours which harmonise with the surroundings, thus minimising camouflage treatment.

The use of large areas of asbestos cement of grey colour on roofs should be discontinued, as this is very conspicuous and is difficult to camouflage.

There is no doubt that effective concealment will play an increasingly important part in future wars, and the need for camouflage in Civil Defence cannot be over-estimated.

OBSCURATION OF LIGHT

War-time lighting restrictions are laid down in the Civil Defence Act, 1939. The operative clauses are Nos. 43 and 46, Part VI of the Act, and these are reproduced herewith for the convenience of the reader.

" It shall be the duty of the occupier of any factory premises, of the owner of any mine and of the persons carrying on any public utility undertaking to take forthwith any necessary measures to secure that in the event of war, throughout any period of darkness—

(*a*) no light is allowed to appear from within any building on the premises, or used for the purposes of the mine or undertaking ; and

(*b*) no lights not within a building remain alight, unless they are essential for the conduct of work of national importance, are adequately shaded, are reduced in power and, save where the Minister otherwise directs, are capable of instant extinction at any time ;

Provided that this sub-section shall not apply to any light exhibited solely in the interests of navigation.

There may be paid out of moneys provided by Parliament, towards the approved expenses of any person on whom a notice has been served under the two last preceding sections in taking the measures specified in the notice, grants not exceeding one half of those expenses."

Clause 47 prescribes a fine of one hundred pounds for failure to comply with the requirements of the Act in this connection and a fine of fifty pounds for each day on which the offence continues.

There is no doubt that the need for stringent economy in all things in a war emergency will automatically ensure the reduction in expenditure of gas and electricity on artificial lighting—indeed, these supplies may quite likely be rationed. Thus the intensity of lighting normal in peace time is likely to be much reduced in times of war.

Apart from this general reduction in illumination it will be necessary to screen lights so as to confine reflections on to the locality illuminated, thus reducing the upwards dissipation to a minimum. To avoid direct observation from the air a lamp can be shielded either by means of a shade or by a painted glass, obscured so as to prevent escape of light above a plane inclined downwards 10° from the horizontal.

To reduce the reflection of light from the illuminated surface the power of the lamp should be reduced to the minimum necessary for safety and the illuminated surfaces should be made as non-reflective as possible.

Where necessary a separate system of blue pilot lights should be installed to enable key men to tend vital plant in a blackout and to enable personnel to reach their shelters in safety when the ordinary lighting is extinguished. The use of dimmer switches on the lighting system will be found of use in turning off all external or exposed lighting on receipt of a warning and signs painted in luminous paint a useful expedient.

A large industrial concern have carried out successful tests on the use of low intensity illumination with blue light for night workers and have found that the operatives soon get accustomed to the darkness and can move about freely. Lighted in this way the large north light factory was not clearly discernible from the air.

Various types of low wattage sprayed lamps are available.

The problem of obscuration is closely related to the problem of the effect of blast and splinters on glass and many industrialists are dealing with both together. The effects of blast from high explosive bombs cannot adequately be imagined, but it would be safe to assume that *all* windows and roof glass in

works or factory premises would soon be blown out under an aerial bombardment. Falling glass is, therefore, a danger which must be dealt with, if work anywhere in a factory is to continue during a raid. Windows in key positions can be maintained much longer if glazed with Super "Armourbex."

Super "Armourbex" glass substitute is clear "Bexoid," 80 thousandths inch thick, reinforced with half an inch wire mesh welded at every crossing. It is a non-flam. cellulose acetate thermoplastic material and costs 31*s*. 6*d*. per sheet, 61 × 27 in.

"Armourbex" is "Bexoid" 22 thousandths inch reinforced with wire gauze, and costs 10*s*. per sheet, 55 × 24 in.

"Bexoid" 3 thousandths inch can be stuck on glass with special solution. The cost is 6*s*. lb. or 1*s*. 5*d*. per sheet, 35 × 24 in. (3 oz.). These materials are obtainable from the British Xylonite Co. Ltd.

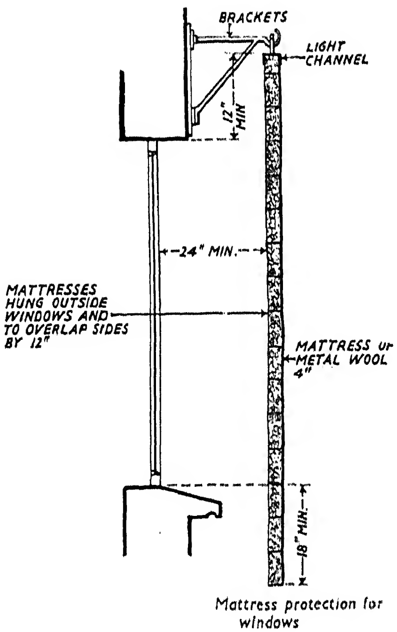


FIG. 271.—Showing metal wool mattress hung outside window.

It is advisable that broken roof glazing should not be replaced during continuance of hostilities but sheets of flat asbestos cement or "Durasteel" substituted. In places where falling glass would be specially dangerous or injurious it would be desirable to instal "Durasteel" sheeting under the glass, thus at the same time adding to the resistance against incendiary bombs.

Where, however, a high degree of splinter protection is required in a window, such as in offices or control rooms occupied during a raid, the installation of "Armourflex" steel shutters as described on pp. 214–218 is recommended.

The provision of blast and splinter protection in window

FIG. 270.—Metal wool safety curtain covering window.

[To face page 588.

openings by the use of any form of solid shutter is normally found prohibitive in cost, but the use of mattresses of metal wool 4 in. thick hung over the window opening generally, as shown on Figs. 270 and 271, affords a high degree of splinter protection.

The "Metwul" safety curtains consist of Grade AS1 steel wool woven to form resilience and resistance mattresses contained in a galvanised woven steel mesh envelope of equal flexibility. Safety curtains should be all appreciably larger than the door, window or machinery to be protected and should preferably be arranged to permit of flexure in a direction away from the source of explosion or blast.

The undermentioned prices include the suspension channel section with hooks but not the brackets for suspending this on the wall. In designing these brackets it is necessary to calculate on an approximate weight of 2 lbs. per sq. ft. area of the "Metwul" safety curtain and treble this figure for the design of the brackets to allow for the resultant drag when the curtain arrests a splinter or is subject to blast. The prices are in steel, 3*s*. 6*d*. per sq. ft., 4 in. thick; alternatively, with galvanised chicken wire envelope replacing woven steel mesh envelopes, 3*s*. per sq. ft., 4 in. thick; in brass, 6*s*. per sq. ft., 4 in. thick, or 5*s*. 6*d*. with galvanised chicken wire envelope. The above prices apply to mattresses of 20 sq. ft. and over and smaller areas are quoted by special arrangement.

It will readily be appreciated that the provision of splinter protection to windows will usually be prohibitive in cost and some kind of glass catching and blacking-out screen may have to be adopted.

The use of mono-chromatic light (say, orange) and a complementary colour embodied in the glass in the windows (say, blue) has been effectively tried out on the Continent. The lamps used are the normal gas-filled metallic filament type except that the bulb is made of an orange glass. It is stated that to test the physiological effect of this light on workers a large factory in France has been fitted with the lamps for over six months and the results have been entirely satisfactory. The blue varnish can be applied by brush or spray to the outside or inside of the glass and during daytime ample light is transmitted through the windows for normal working purposes.

It is also claimed that as a result of exhaustive tests carried out in this country the use of the complementary colour method of obscuration is permitted by the A.R.P. Department of the Home Office. Lamps and varnish can be stocked in peace time and the system installed very rapidly in time of war.

On the basis of 100,000 sq. ft. of glass and purchasing the obscuring paint at 16*s.* 6*d.* per gallon with a coverage of 360 sq. ft., two coats, the total cost of painting works out at £200. Assuming that there is an equivalent of 450 lamps of 300 watts each, the cost of the special lamps would be of the order of £337 or about 12*s.* per sq. of 100 sq. ft. of glass.

It is obvious, of course, that were such windows broken the whole factory would have to be blacked out and work would cease.

Many companies have found that with half the window and roof glazing permanently obscured they are quite well able to carry on in the daytime, and if this can be done the problem is considerably reduced in magnitude.

In the obscuration of light, the main factors which require consideration are :—

(1) Opacity.
(2) Waterproof qualities—in case the glass should break.
(3) Protection from flying glass.
(4) Non-inflammability of obscuring materials—desirable but not essential.
(5) Moth-proof qualities—especially in the case of food factories.
(6) Internal or external application.
(7) The desirability of admitting light during the day whenever this is practicable.
(8) Gas proofing—less emphasis is now being placed on this aspect.

Paint

The simplest way of blacking out is to spray on paint internally or externally, and in a factory of moderate size this may take from two to three days.

A paint selected for this purpose should be waterproof and sufficiently opaque in one coat only. As the cost of removing ordinary paint may be three or more times the cost of applying

it, the paint used should also be one that can be removed by a convenient and inexpensive process when required. The external application of the paint is usually the cheapest and best, as it thus prevents glare from the glass and assists in the camouflage.

A suitable paint can be made up as below:

1 cwt. black ground-in oil,
$\frac{1}{2}$ cwt. paste dryers,
2 galls. of turpentine,
$\frac{1}{2}$ gall. of boiled linseed oil, and
1 pint of terebene, giving
10 galls. of black-out paint.

A suitable stripper would consist of—

5 galls. of benzene,
$3\frac{1}{3}$ galls. of acetone,
15 lb. of paraffin wax, giving
10 galls. of paint remover.

The glass can be painted with black-out black paint and the following are the prices: 1 cwt. kegs, 45*s.* per cwt., keg free; $\frac{1}{2}$ cwt. kegs, 46*s.* per cwt., kegs free; $\frac{1}{4}$ cwt. kegs, 47*s.* per cwt., kegs free; covering capacity 400–500 sq. yd. per cwt., applied by spray or with brush as desired.

As already pointed out the use of paint on existing glass may prove a very expensive expedient since damage to the glass which is bound to result in a bombardment, will mean the whole of the light in the factory would have to be extinguished until the glass had been repaired. In any event, to prevent danger from flying splinters it would be desirable to instal close mesh galvanised wire netting on frames; the cost of this would be of the order of 7*d.* per sq. ft.

"Synthaprufe" is a mixture of bitumen and rubber, produced by Gowan's Paints, Smallbrook Street, Birmingham, at a cost of 5*s.* 9*d.* per gall.

Like "Latex," it will easily peel off the glass and works out at approximately 1*s.* per sq. yd.

A special flat paint, proposed by the Office of Works for internal use on glass to give obscuration with one coat only, is made to the following formula:—

Pigment: 57 per cent. (by weight), consisting of carbon black and a filler like barytes, asbestine or whiting.

Medium : 43 per cent. (by weight), consisting of gum and oil, 40 per cent., and volatile thinners, 60 per cent.

The gum and oil vehicle consists of fossil resin, tung oil and linseed oil.

It is usually desirable to obscure light by shutters of material such as ply board, Essex board, etc., or wood covered with a waterproof material, which would obscure light, hold glass and prevent it from flying into the room in the case of blast and which would also be weatherproof in the case of fracture of the window.

Shutters which can be taken down during the day and which can be made gas-proof and applied inside the window are an advantage, and a portable arrangement used by the Office of Works on Government buildings involves the use of rubberised cotton fabric stretched on a light frame and fixed on the inside of the window with ball catches, so that under the action of blast pressure the whole shutter is blown inwards and left hanging on special suspension pieces of india-rubber.

This is a safety factor and is a system which has been subjected to actual test. The fact that the shutters are light and easily fixed enables them to be handled easily by youths or girls employed in the factory (see Fig. 76).

Messrs. Textuff Limited, of Lancaster, are producing textiles such as cotton and hessian impregnated with a cellulose solution. It is claimed to be grease, water and germproof, non-cracking, not damaged by mustard gas or damaged by subsequent boiling for decontamination. Material suitable for the strengthening of window glass costs 5½*d.*–7½*d.* per yd. It can be obtained in any colour, including greens and black, and can be stuck to the glass with normal adhesives or stretched on the frames previously described. The prices for the black-out material are 1*s.* 1½*d.* per yd., 36 in. wide, or 1*s.* 8*d.* per yd., 48 in. wide. Details of the portable shutters referred to are shown in Fig. 76, the estimated cost being 1*s.* 2*d.* per sq. ft. of window area.

A cheaper arrangement of gas and light obscuration screen for vertical windows is shown in Fig. 73, the estimated cost being 5*d.* per sq. ft. The rubberised cotton fabric is fixed upon the two wooden uprights, which are wedged in position by the horizontal members of the frame hinged to one side as indicated.

During the day the whole arrangement pulls out for convenient storage and when wedged into position forms a gas tight, light obscuring screen which is sufficiently loose to yield under blast pressure and is therefore calculated to survive very much longer than would a rigid screen. The use of light paper

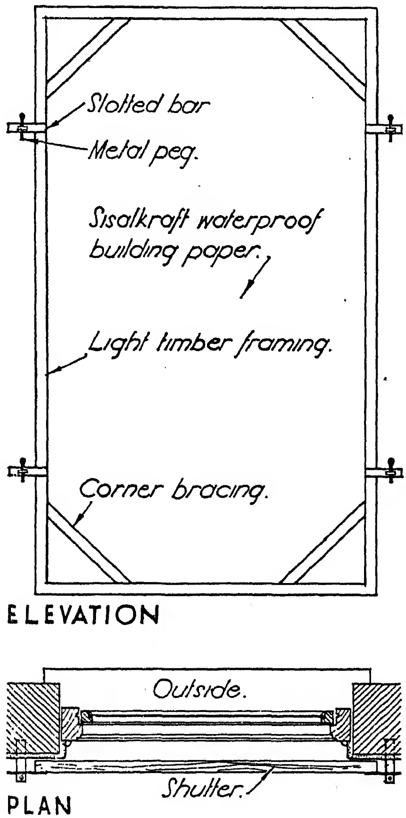


FIG. 272.—Cheap form of light-obscuring screen.

screens on batten frames, as shown in Fig. 272, is another cheap arrangement.

Suitable material would be—

(*a*) Lyte-tite paper.

48 in. wide . . .	25*s*. per 100 yds.
60 in. „ . . .	31*s*. „ „

Messrs. Medway Paper Sacks, Ltd., Larkfield, Kent.

(*b*) Sisalkraft 6-ply brown paper. It reflects 80 per cent.

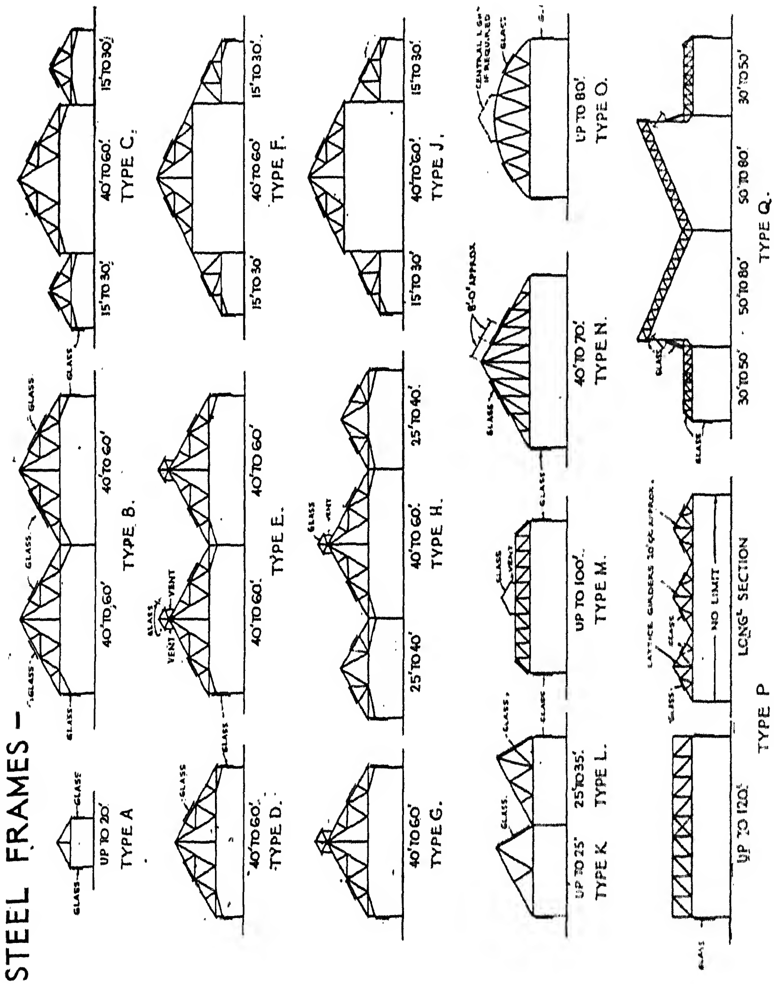


FIG. 273.—Outline sections of factory buildings.

of the light falling upon it but transmits none. It is also water, wind, tear-proof, and is suitable for making up into roller blinds. Prices :—

36 in. wide . . .	6*d*. per lin. yd.
42 ,, ,, . . .	7½*d*. ,, ,,
48 ,, ,, . . .	9*d*. ,, ,,
54 ,, ,, . . .	10½*d*. ,, ,,
60 ,, ,, . . .	1*s*. ,, ,,

Messrs. J. H. Sankey & Son Ltd.

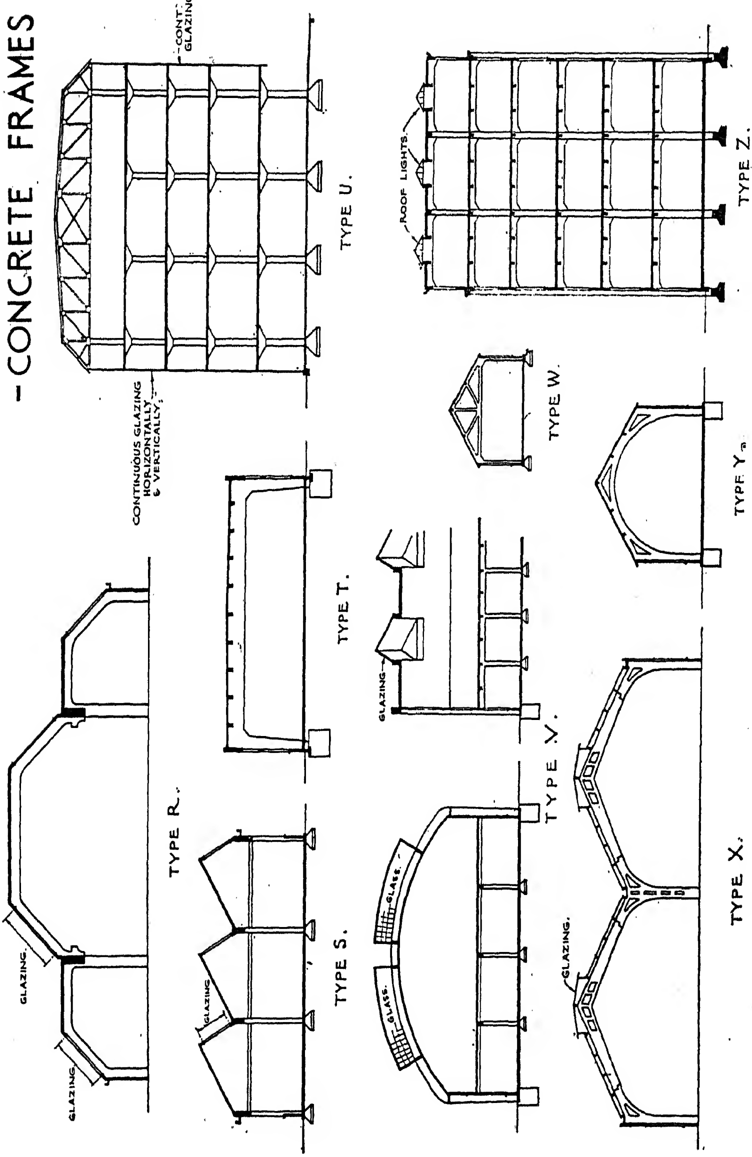


FIG. 274.—Outline sections of factory buildings.

An approximate idea of the cost of blinds made up with Sisalkraft black-out blind material may be obtained from the following :—

TABLE CVI

Width.	Length.	Type A.	Type B.	Type C.
3′ 6″	4′ 0″	2/6	4/3	5/6
4′ 6″	6′ 0″	3/6	5/6	7/6
6′ 0″	8′ 0″	4/6	7/6	12/-
9′ 0″	9′ 0″	5/-	11/-	15/6
12′ 6″	9′ 0″	12/-	24/-	32/-
15′ 0″	12′ 6″	16/-	30/-	48/6

Type A. Eyeletted at top with egg lath at bottom.
Type B. Flange roller.
Type C. Automatic spring roller.
Delivery and fixing charges extra.

(*c*) Holland, Lancaster and other fabrics.

Fig. 273 and 274 show sectional outlines of factory buildings, each type of which presents special light obscuration problems.

Fig. 275 shows the interior of a workshop illuminated with continuous roof glazing, which is a not unusual arrangement.

It will be noticed that the distribution of the intensity of illumination is uneven and that the camouflage, blacking-out and protection of the glass is difficult.

On the other hand, however, the use of Robertson's sheet lights, as shown in Fig. 276, gives more even distribution of illumination and enables the glass area to be reduced without reducing the average intensity of the light on the working plane.

Fig. 277 shows a sliding tray which enables sheet lights to be covered in a few seconds and which provides protection for the interior against flying splinters of glass broken by an explosion.

The shutters slide on rods, and are pulled to one side by means of a wire, which serves to open or close a considerable number of shutters in a single row, so that all the glass in a large number of sheet lights may be obscured very quickly.

FIG. 275.—Showing effect of continuous roof glazing on the lighting of interior of workshop. The glazing arranged in this way is difficult to black out and to camouflage.

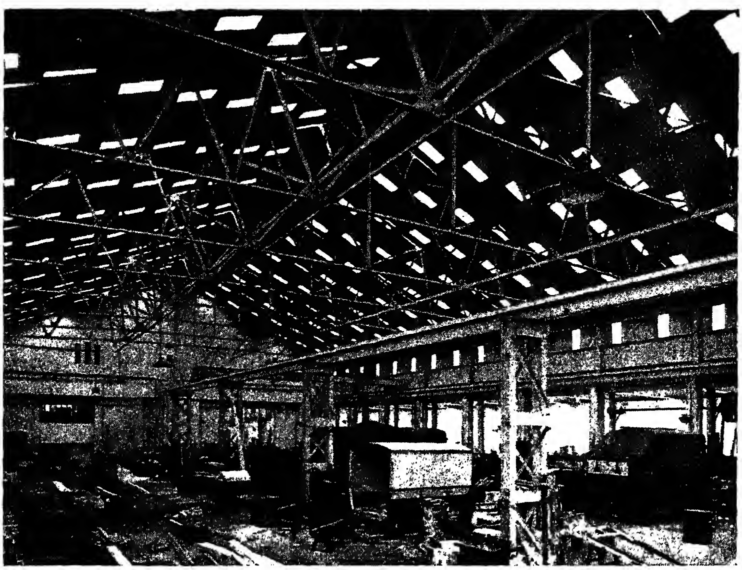


FIG. 276.—Showing even distribution of light in interior of workshop lighted with Robertson's sheet lights. By this arrangement the glass area can be reduced without reducing the average intensity of interior illumination.

[*To face page* 596.

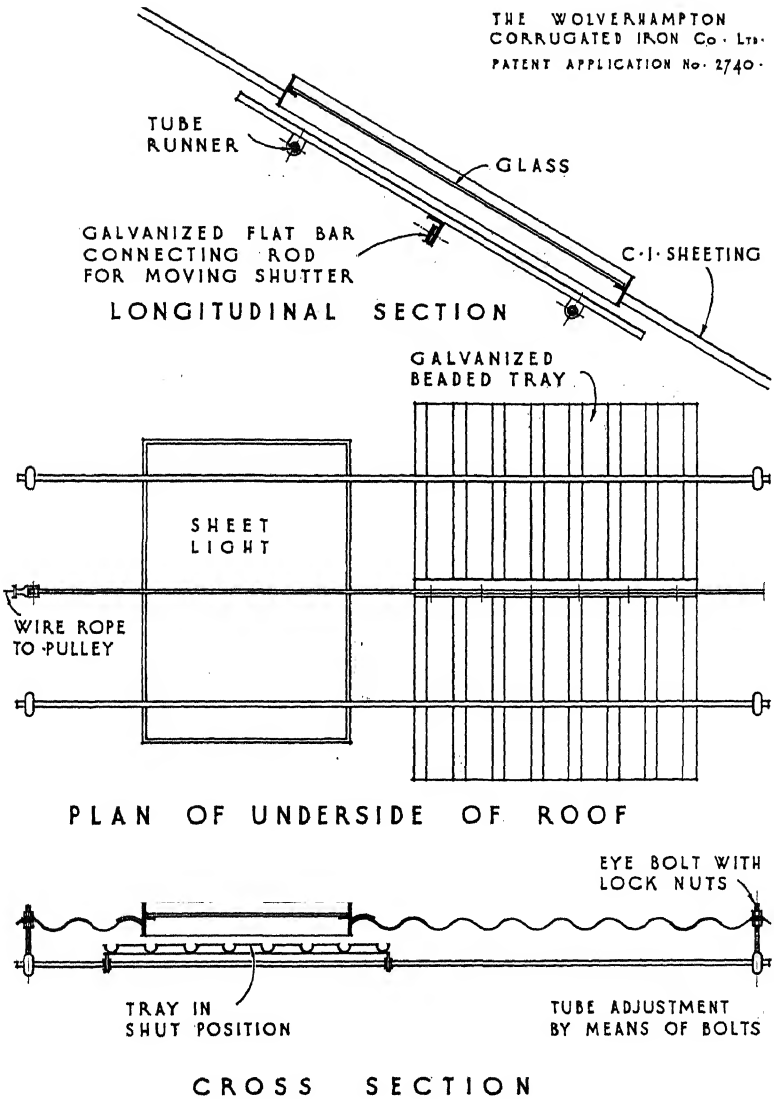


FIG. 277.—Sliding tray under roof lights providing light obscuration and protection against falling glass.

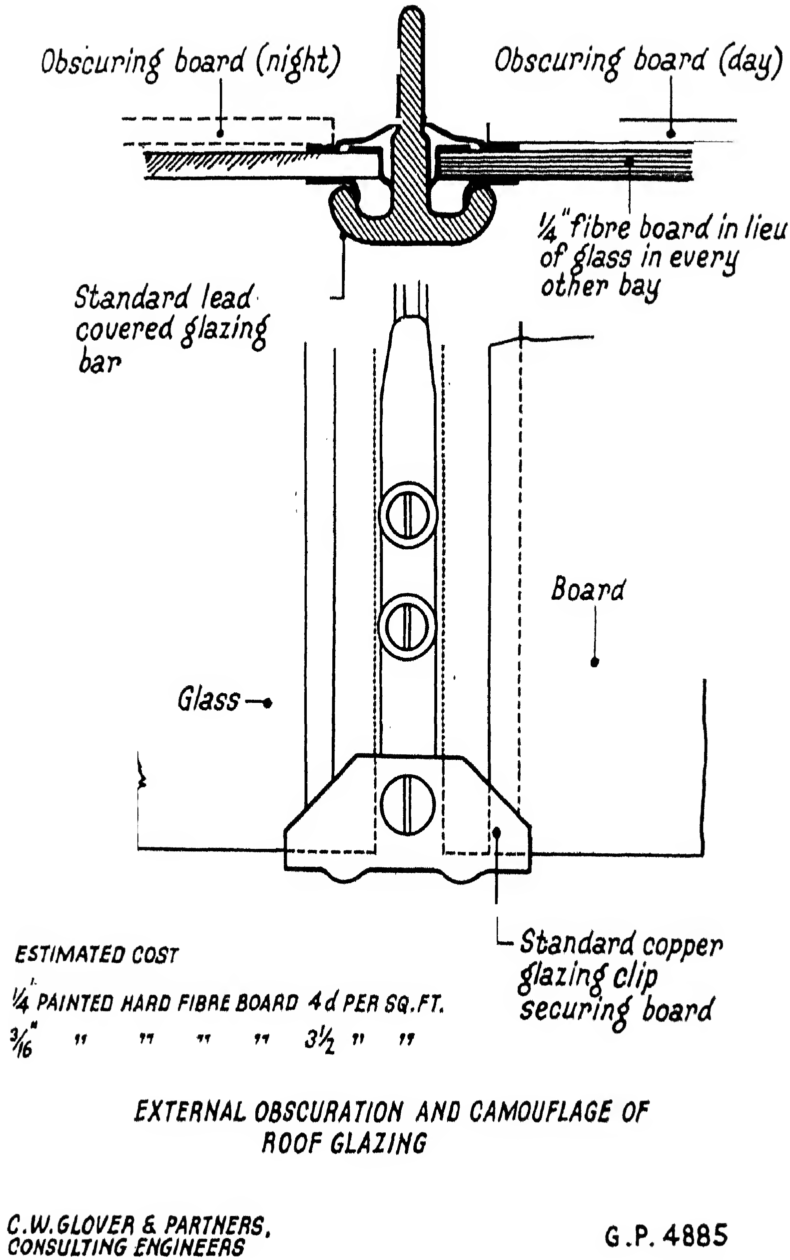


FIG. 278.—Showing method of camouflaging and obscuring light through roof glazing accessible from outside.

For the obscuration of light through roof glazing a number of alternatives present themselves.

Where it is possible to get access to the roof glazing conveniently from the outside, some such arrangement as shown on Fig. 278 will be found the most convenient. By this arrangement the glass from every alternate bay in the roof glazing is removed and stored against the requirements of repairs during an emergency, and in place of the glass opaque painted boards of $\frac{1}{4}$ in. fibre board are installed. By this means 50 per cent. of the light would be permanently blacked out and on the obscured positions accommodation for the remainder of the obscuring boards can be obtained.

To avoid the expense and difficulty of installing complicated hinge devices over the existing glazing bars, the arrangement shown on the drawing can well be adopted, as the obscuring boards need only be $\frac{3}{16}$ in. thick and this easily clips under the standard copper glazing clips at the base of the bar. The position of the obscuring board by day and by night is shown on the sketch. The estimated cost of $\frac{1}{4}$ in. painted hard fibre board is 4*d.* per sq. ft. and $\frac{3}{16}$ in. painted hard fibre board, 3½*d.* per sq. ft.

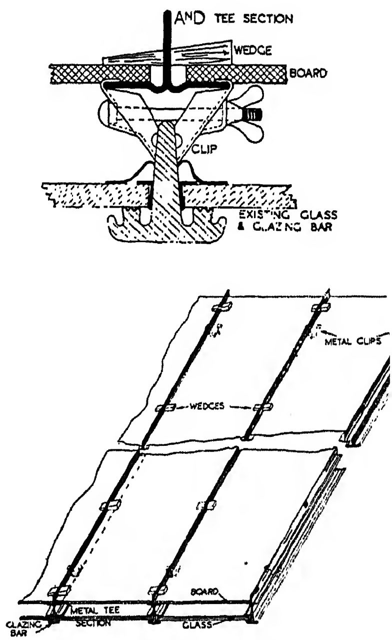


FIG. 279.—Showing Anderson clip and tee for the wedging of fibre boards in position over glazing.

Fig. 279 shows C. F. Anderson & Son's method of clipping an additional light steel tee section to glazing bars to provide wedge fixing for fibre board covering for roof glazing and windows.

It can be used on any type of glazing bar and fixed by unskilled labour.

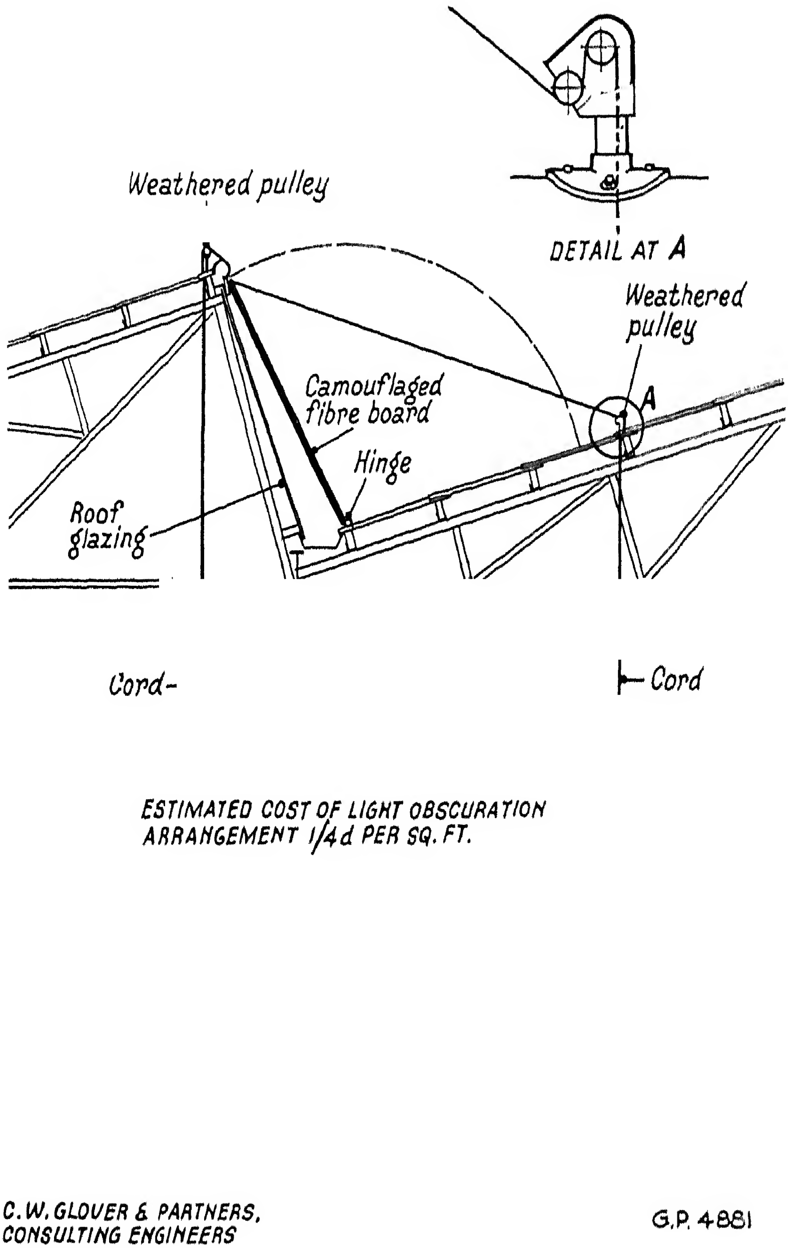


FIG. 280.—Method of light obscuration and camouflage for North light roof using external shutters.

The slotted tee sections are permanently placed in position by means of special clips and left until it is necessary to obscure the light. When required, opaque boards can be fixed in a short time by means of wedges which, being fixed without nails or screws, can be removed quickly and easily without damage.

An adaptation of this method can be used externally or internally on vertical windows.

An arrangement for operating north light obscuration from the inside of the building is indicated on Fig. 280. From this it will be seen that the camouflaged fibre-board shutters are fixed to a hinge on one side of the valley gutter so as to enable them to swing over to the sloping portion of the roof during the day and to be pulled over the roof glazing during the night, generally as indicated on the sketch. The estimated cost of this installation is 1*s*. 4*d*. per sq. ft.

Fig. 281 shows some cheaper alternatives and which include a vertical roller blind over the inside of the louvres at 8*d*. per ft. super, and a camouflaged tarpaulin on rollers operated from the ridge, generally as indicated over the top of the lantern light. The estimated installed cost is 1*s*. per ft. super.

The opaque sliding shutter shown in Fig. 282 has the advantage that there is little in it to go wrong and it can be easily operated even in high wind; the estimated cost is 1*s*. 11*d*. per sq. ft. installed.

A convenient method of installing opaque shutters is shown in Fig. 283, from which it will be seen that each glazing bar is drilled and tapped for $\frac{3}{16}$ in. dia. set screws at 12 in. c/c, and by which a hollowed-out distance piece of timber and a cover strip of metal is fixed. Shutters consisting of $\frac{3}{16}$ in. plywood and $22\frac{3}{4}$ in. wide are inserted, as indicated, and operated as shown in the sketch. One-third of the glazing is thus permanently blocked out by the fixed shutter at the top, the lower sections being pulled up by the cord.

The advantages of this system are :—

(1) The shutters can be installed and operated from the inside.
(2) They fall to the black-out position when the cord is released or accidentally broken.
(3) They catch broken or shattered glass ; and
(4) The cost is about 7*d*. per sq. ft. installed.

The disadvantage is that being installed on the inside they

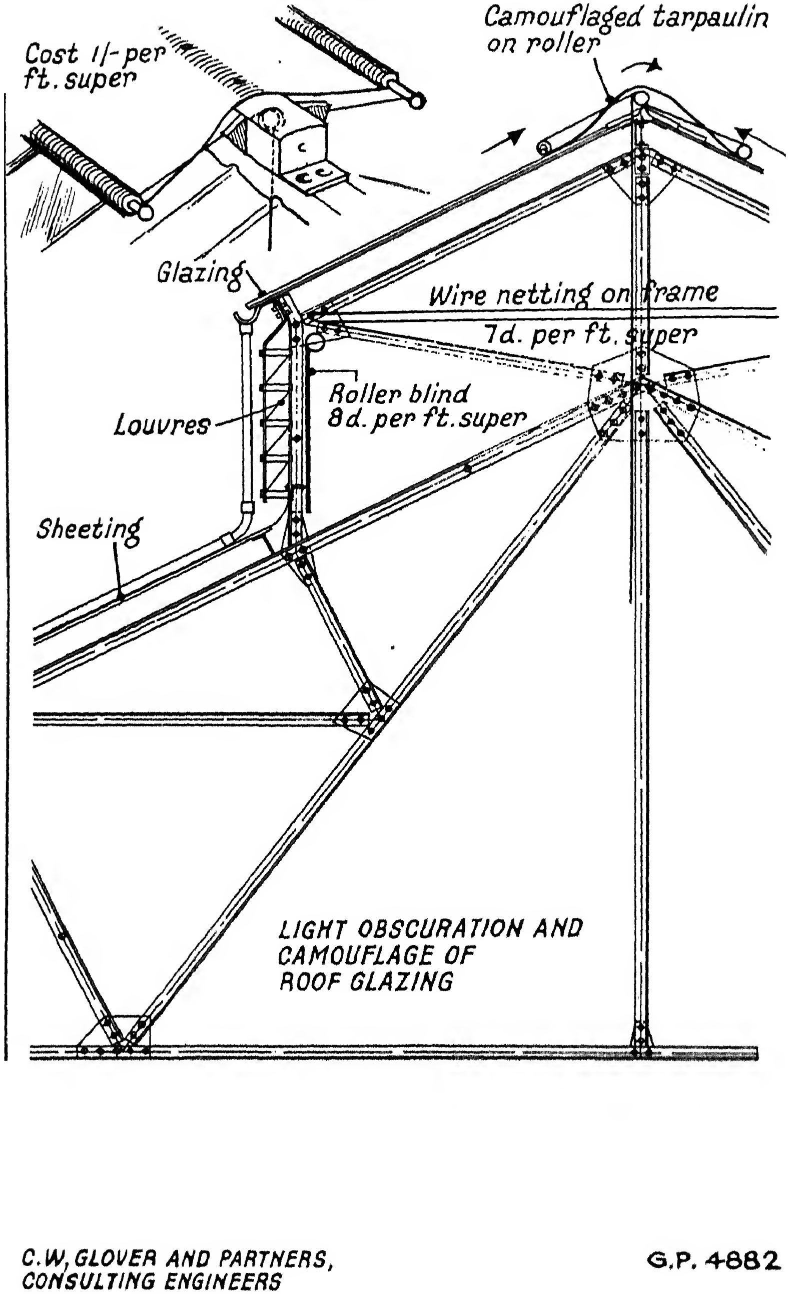


Fig. 281.—Showing methods for light obscuration and camouflage of roof glazing.

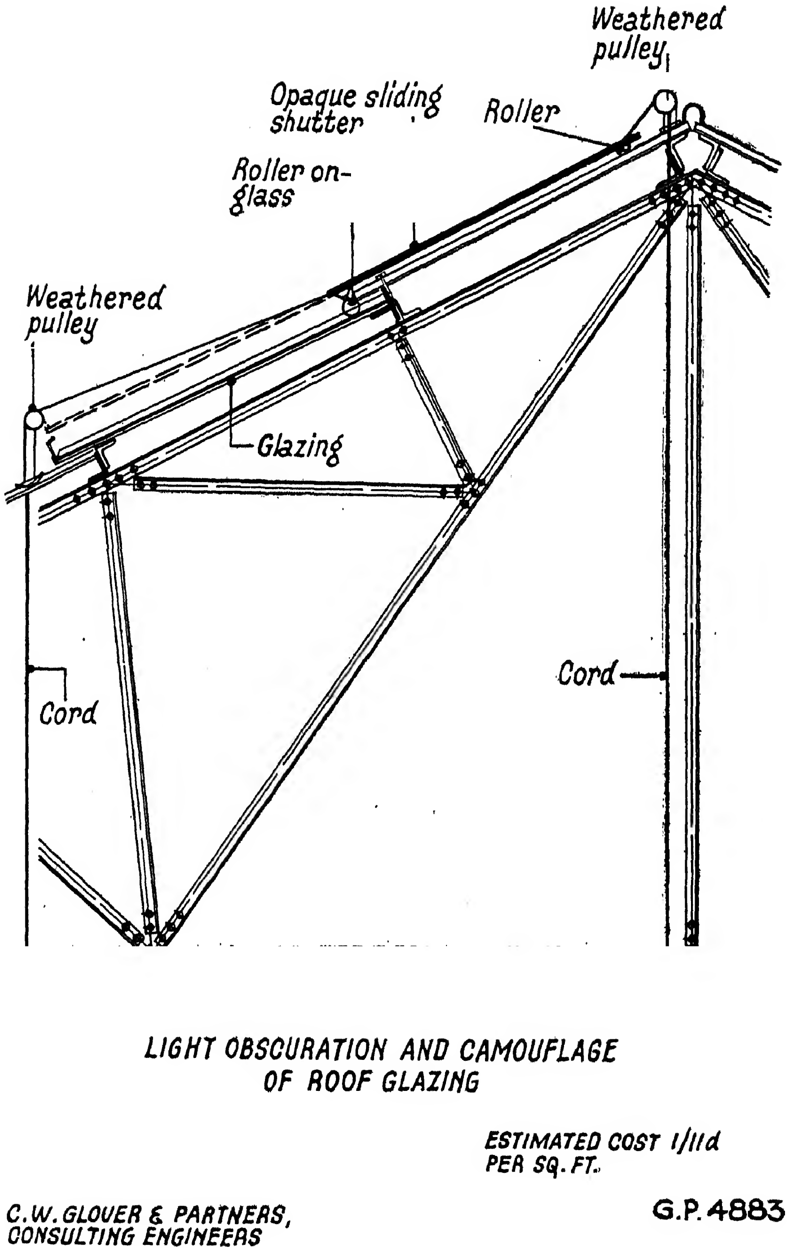


Fig. 282.—Showing use of sliding opaque shutters operated from the inside for camouflage and light obscuration through roof glazing.

are of no use in the prevention of flashed reflections of the light of the sun or moon and are of no assistance to camouflage.

The external sliding shutters shown in Fig. 284 are, however, of use in camouflage and light obscuration.

The details have been developed with a view to the utilisation of available materials, although specially rolled sections would no doubt make a neater job.

The arrangement is to have welded window sashes some 4 ft. 6 in. wide and of a length sufficient to cover the length of the roof glazing. The sashes are filled with opaque and

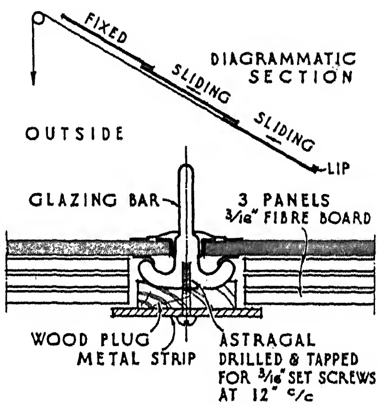


FIG. 283.—Opaque sliding shutters inside roof glazing.

weathered board so that when every alternate pair of panes of roof glazing are replaced with opaque board it is possible to expose about 50 per cent. of the original glass area to the transmission of light, or to black out completely by the movement of the train of frames some 4 ft. only.

The tow wires can be manually operated or by motor gear with push-button control. The estimated cost is 2*s.* 4*d.* per sq. ft. of original glazing area installed with hand gear operation or approximately 3*s.* per sq. ft. motor driven.

By motor operation it is possible to black out in thirty seconds irrespective of the size of the roof.

Fig. 285 shows the George Kent method of installing internal wood sliding shutters, which have the advantage of producing a reasonably weather-tight roof covering when in the " blacked-out " position.

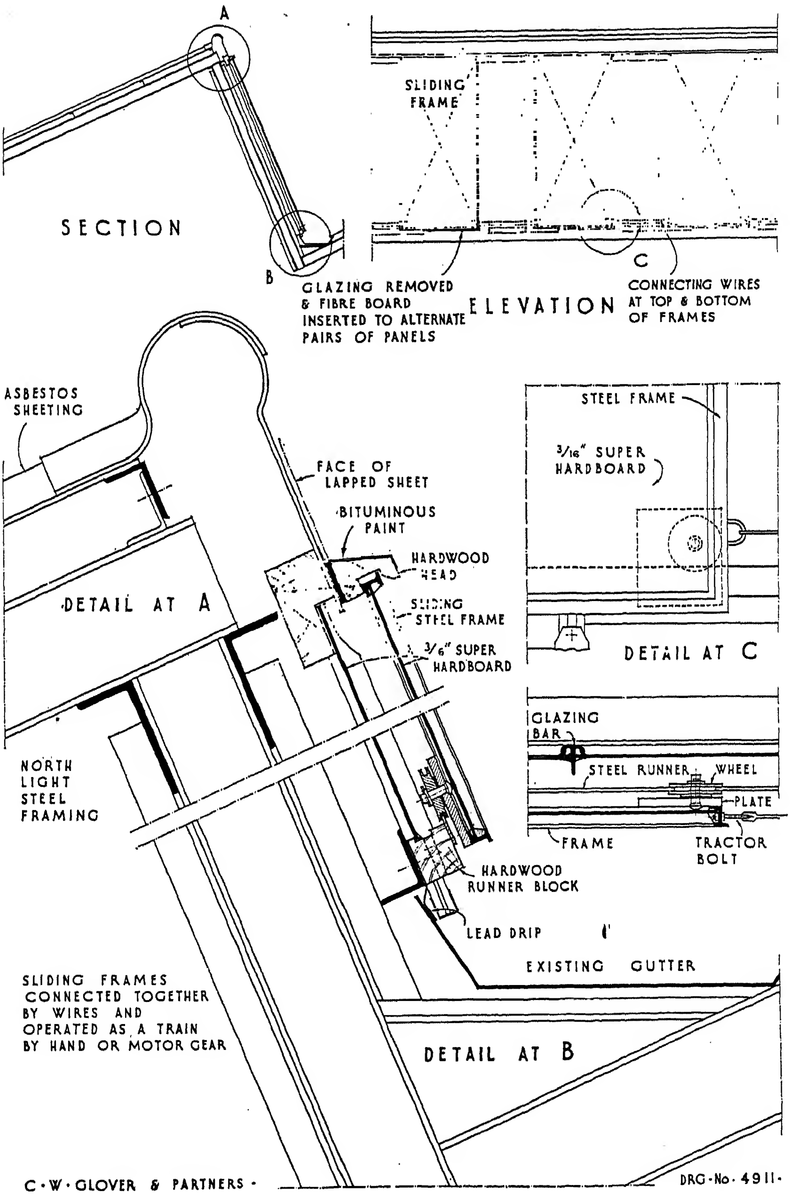


Fig. 284.—External opaque sliding shutters for North light glazing.

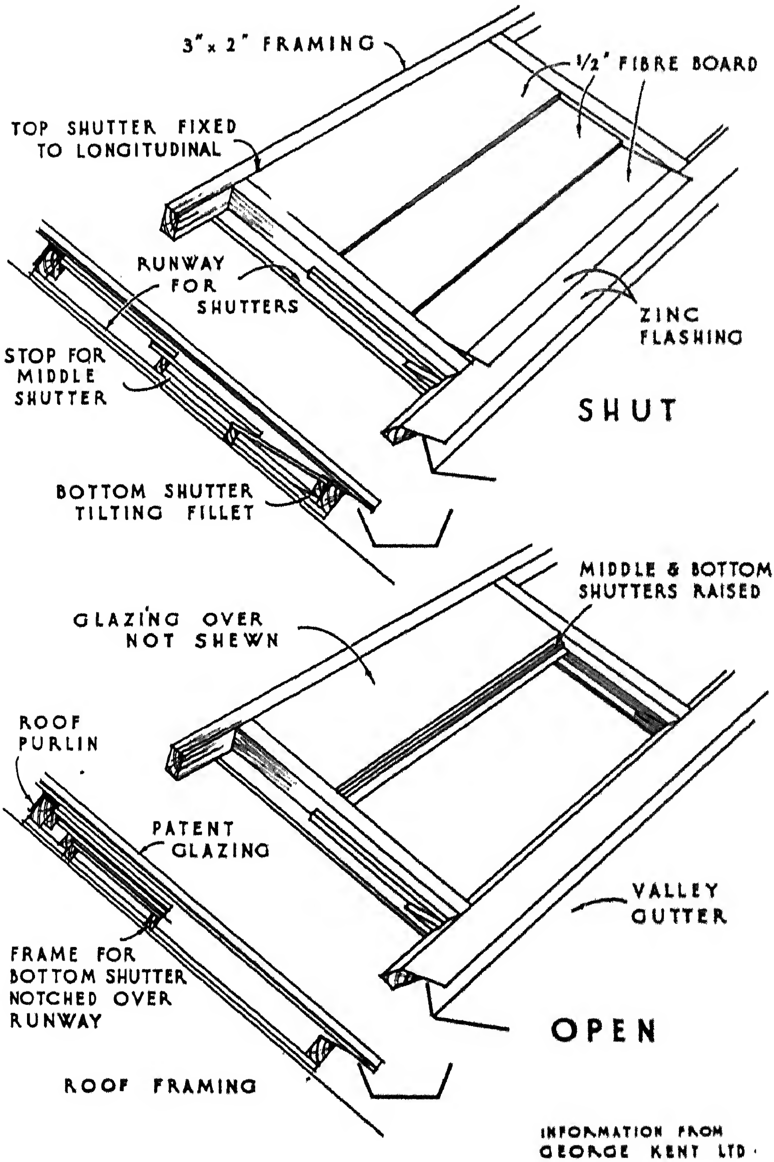


FIG. 285.—Interior sliding opaque and weathered shutters for roof glazing.

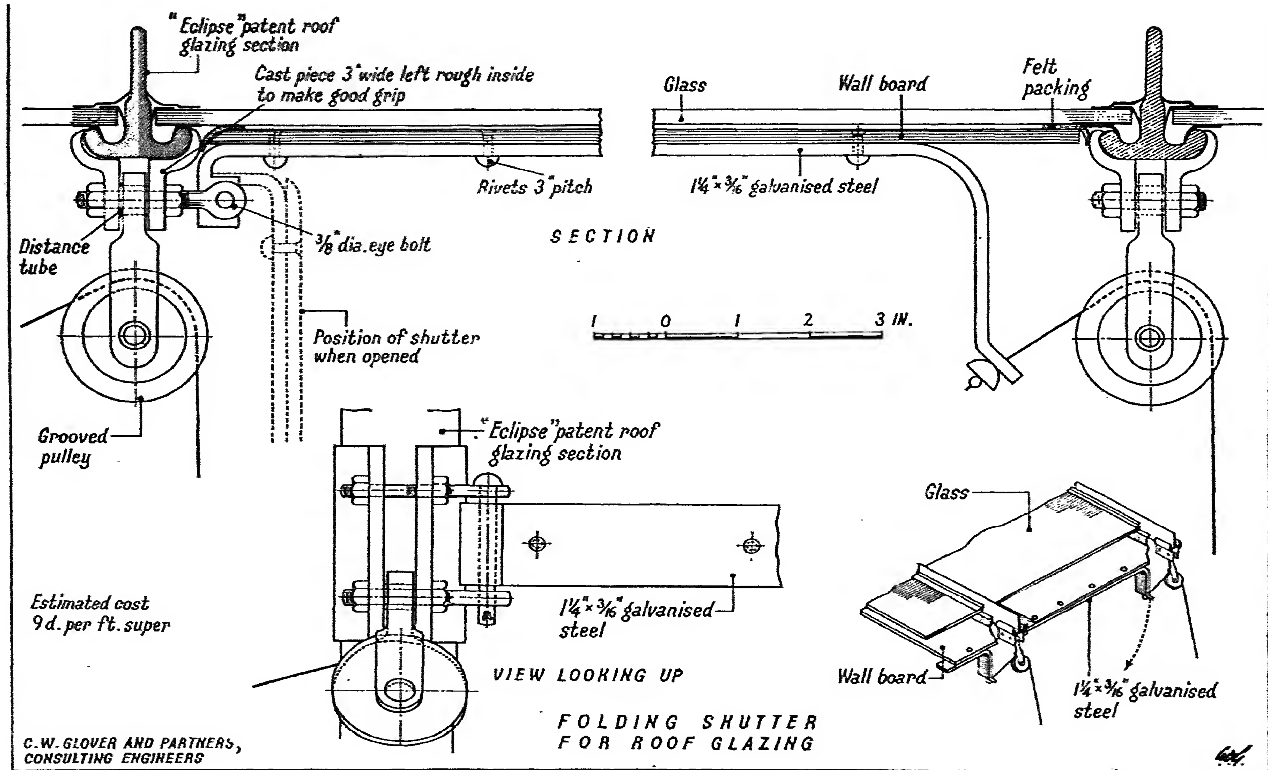


FIG. 286.—Showing internal opaque hinged shutters which can be attached to roof glazing.

This is a specially useful feature as when the roof glass is broken the interior of the building can be protected from the shattered glass, and also from the weather until the glazing is repaired.

The approximate installed cost is 1s. per sq. foot of original glazed area.

A form of internal hinged shutter is shown in Fig. 286.

Glow from Furnaces, Plant, etc.

It is important to shield the glare from blast furnaces, cupolas and other similar plant, from reaching the skies and indicating the presence of industrial plants.

There is no general method of prevention suitable for universal application and each plant must be examined and dealt with on its own merits. The following are, however, methods which have been successfully employed:

(1) The glare from the top of active blast furnaces can be screened by the use of large fireproof louvred hoods carried over the charging platforms of the furnaces.

(2) The top flames from cupolas can be dealt with in a similar manner.

(3) The glow from the inspection holes, slag pipes and other external apertures in cupolas can be screened with large sheds over the charging platform and at ground level.

(4) The reflection of light from kiln chimneys can be dealt with by the use of asbestos sheet baffles.

(5) The glow from open-sided foundry sheds can be minimised by the construction of louvred sides having a large overhang.

(6) Ventilating gaps and louvres in lighted workshops can be screened by external hanging shutters arranged to pass ventilation through a form of light lock.

(7) Light locks, similar in arrangement to the air locks described on pp. 113–117, must be used on all doorways used after dark, when the interior is brightly lighted.

(8) Wall fans can be screened permanently by the use of large external louvres in reinforced concrete or similar material.

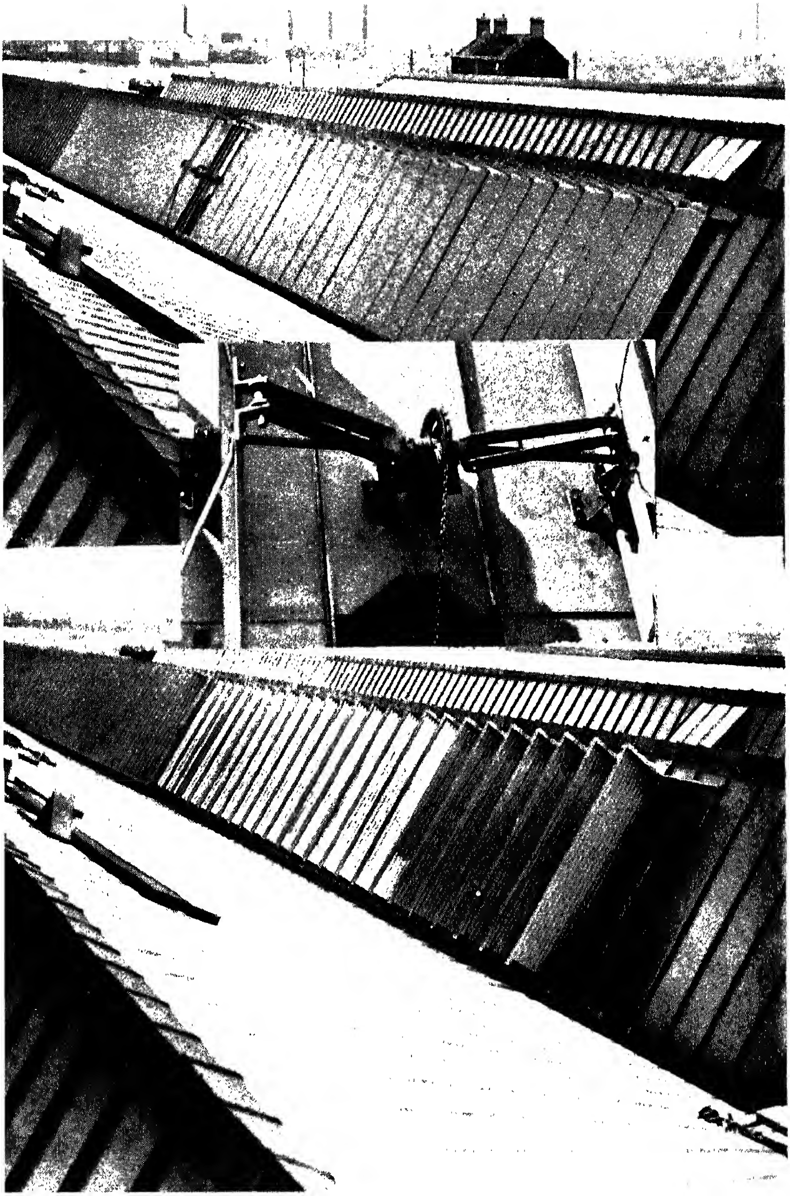


FIG. 280A. Hills' patent louvred shutters for light obscuration—admitting maximum daylight when open and affording opaque and weatherproof covering when closed.

(Courtesy Hills Patent Glazing Co., Ltd.)

[*To face page* 608.

CHAPTER XV

AIR RAID PRECAUTIONS IN FACTORIES

FOR detailed information regarding the organisation of an air raid precautions scheme for an industrial establishment the reader is referred to "Air Raid Precautions for Government Contractors," issued by the Admiralty, War Office and Air Ministry.[152] The principles recommended in this pamphlet are based upon visits paid to over 600 factories since the emergency at the end of September, 1938. At these visits individual needs and difficulties were thoroughly discussed with the single aim of arriving at reasonable solutions which managements would find useful.

The situation in every factory differs and rules cannot be applied without regard to local conditions, but the information given in the pamphlet is of general value and should not be set aside for other than exceptional reasons.

Briefly the general considerations are that the personnel and plant in factories should be protected against the effects of air raids in order to give security and confidence to the workers and to enable production, which is an essential part of the national effort, to be maintained at the highest possible rate. Under the requirements of the Civil Defence Act such schemes must be prepared in peace time ready for immediate operation in an emergency and physical protection against all hazards except a direct hit provided as already laid down herein.

Further, the training of personnel is now obligatory and the following notes will be of interest and use.

Training

Certain duties, such as first aid, fire-fighting, defence against gas, decontamination, rescue and salvage work, cannot be performed without previous training. It is therefore essential that in peace time sufficient personnel should be trained in these duties. Table CX gives the recommended scale upon which A.R.P. personnel should be organised.

First aid training can be obtained in the St. John Ambulance Brigade, the British Red Cross Society, the St. Andrew's Ambulance Association and the Scottish Branch of the British Red Cross Society, or any special classes arranged by the local authorities. Home Office Circular No. 703189/19, dated August 26th, 1938, addressed to local authorities, gives information on this question.

Fire fighting training can be obtained by arrangement with the local fire brigade. Training in rescue and salvage work can usually be arranged by the employer himself.

As regards anti-gas defence, the best method is to arrange with the local authority for personnel to undergo a local course, where an L.A.R.P. certificate can be obtained. On return from a course such men should be able to train others in these duties.

In the case of decontamination squads, arrangements should be made with the local authority for the instruction of this personnel to be given by an instructor A.R.P.S.

(*Note.* Extended courses of training, including incendiary bomb control and elementary methods of protection against H.E. bombs, are available at the Home Office schools at Falfield and Easingwold. Persons passing the course at these schools and the local instructors who are given the extended training will hereafter be known as Instructors A.R.P.S. and L.A.R.P. respectively instead of C.A.G.S. and L.A.G.C.).

The standards of passive protection recommended are as laid down in the Code of Practice summarised in Chapter XII.

Accommodation required for the Protection and Operation of A.R.P. Services.

These will consist of :—

(*a*) A.R.P. control post and intercommunication personnel.
(*b*) First aid post staff } Combine if possible and allow
(*c*) Cleansing personnel } for both sexes.
(*d*) First aid parties.
(*e*) Fire fighting squads and fire watchers.
(*f*) Rescue and salvage squads.
(*g*) Decontamination squads and gas searcher personnel.
(*h*) Key men who have to remain tending their plant.

All the above must be provided with splinter-proof and

incendiary bomb-proof accommodation for personnel and equipment at, or as near as possible to, their probable scene of activity. Failing existing accommodation which could be utilised or adapted at short notice, it will be necessary to provide these premises in peace time.

Accommodation for (*b*) and (*c*) in addition to being splinter-proof and incendiary bomb-proof must be gas-proofed. If existing first aid premises or other buildings cannot be utilised or adapted at short notice, then this accommodation must be provided in peace time. Accommodation constructed below ground is safer and can be provided more cheaply than above ground.

Protected accommodation for such men as fire watchers and key men will usually be sited in the corners of buildings and is best constructed with sandbags.

Intercommunication

Internal arrangements will be necessary for communicating the air raid warning instantly to all personnel.

Internal communication will be required from the control post to the A.R.P. services, and to specific points within the factory.

Buildings and Plant

Note. The definition of vital plant is key plant upon which the output of a factory as a whole depends.

(*a*) *Lateral Protection against Splinters and Blast.* The walls of buildings containing vital continuous processes or vital plant should be of splinter-proof thickness up to at least the height of the top of the machinery enclosed. If the cills of windows and openings are below the height of the vital plant, splinter-proof protection must be provided at these places up to at least the height of the plant enclosed.

In the case of shops where walls are not of splinter-proof thickness, or in large shops containing groups of vital plants or isolated vital plants, these plants should, if feasible, be protected by splinter-proof erections or walls not more than 50 ft. away from the plants.

(*b*) *Overhead Protection.* When glass in roofs and windows has to be repaired it should be replaced with wired glass. The

standard in new construction for all glass in roofs and windows is wired glass.

The standard thickness of roof to be aimed at is 6 in. of concrete for buildings containing vital plant. In large shops, where it is impracticable to give complete overhead protection against light incendiary bombs and light *débris*, vital plants which are vulnerable should be protected by the erection of canopies of ¼ in. steel.

Fire

Equipment must be provided for dealing with fires and incendiary bombs in buildings.

All fire-engines and pumps should be considered as vital and housed in splinter-proof and incendiary bomb-proof shelters or buildings.

It is important that alternative sources of supply of water should be arranged wherever possible.

Lighting

During time of war lighting restrictions will be enforced, and no lighting will be allowed to be visible from the air during the hours of darkness. Only in exceptional circumstances will any partial relaxation of these requirements be allowed.

Emergency lighting will be required to assist in the evacuation of buildings to A.R.P. accommodation. Independent lighting (battery, oil or candle lamp) must also be provided in all A.R.P. accommodation.

Alternative Sources of Supply (Electricity, Gas and Water)

Both in new schemes and in existing factories, where possible and within reasonable financial limits, alternative sources of supply should be arranged.

This is specially necessary in the case of water for fire-fighting purposes.

APPLICATION OF THE STANDARDS

1. Protection of Personnel

General Rule. To minimise casualties from a direct hit of an H.E. bomb, no party should consist of more than fifty

persons together. Only in very exceptional circumstances should this rule be departed from, and in such cases special measures for protection will have to be taken. Each party must be segregated from every other party, and provided with the necessary protection against blast, splinters, light incendiary bombs, and light *débris*. Unless specially ordered, accommodation for personnel should not be made gasproof, but should be capable of being gas-proofed if necessary. It is important that every worker has his respirator in his possession at all times.

Every occupied shelter or space must have its own emergency exit.

All protective walls between parties must extend from side wall to side wall and up to the ceiling.

2. Protection and Operation of A.R.P. Services

General Rule. All accommodation for the personnel and equipment of the A.R.P. services must be provided with at least the standard of lateral protection against splinters and blast, and the standard of overhead protection against light incendiary bombs and light *débris*. The remarks in Para. 1 regarding gas equally apply to A.R.P. personnel except that the first aid and cleansing centres must be gasproofed.

(*a*) *A.R.P. Control and Intercommunication Personnel.* A protected control post is required from which a responsible official can maintain control over the various A.R.P. services and personnel, by telephone with an alternative messenger service.

The post is best near the permanent office of the official in control, but in large factories subsidiary control posts may be necessary, in which case the organisation will have to be duplicated as required.

(*b*) *First Aid and Cleansing Personnel.* It is essential that the whole of the premises chosen should be protected and gasproofed and that the layout and area conform generally to the Standard laid down in A.R.P. Handbook No. 6, and Home Office pamphlet, First Aid Posts, dated April, 1938.

Separate first aid and cleansing facilities will be required for men and women. The proportion of women to men may

increase considerably in war, and this factor should be borne in mind when accommodation is selected.

The cleansing centre should adjoin the first aid post. Slightly wounded contaminated personnel can be cleansed in the cleansing centre before entering the first aid post. Seriously wounded personnel who are also contaminated must be cleansed and medically treated in the first aid room,

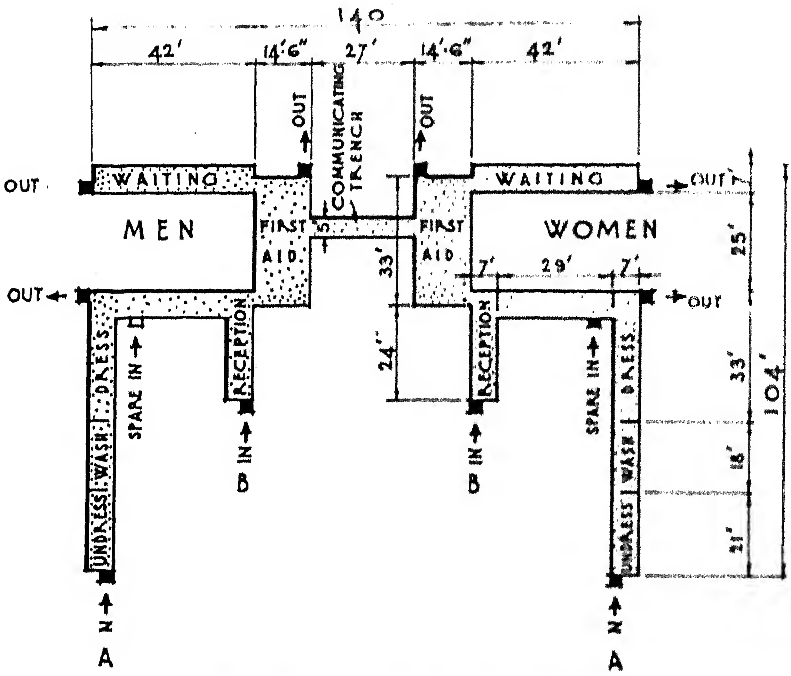


FIG. 287.—First aid and cleansing centre for men and women.

having had their clothing removed in the waiting-room as expeditiously as possible.

Wash-places and lavatories where hot water facilities exist may often be utilised as cleansing centres. Such accommodation must be suitably protected and gasproofed.

Weatherproof sheds should be constructed at the entrance to cleansing centres, where contaminated persons can take off and leave behind their contaminated clothing.

The design of a suitable below-surface first aid and cleansing

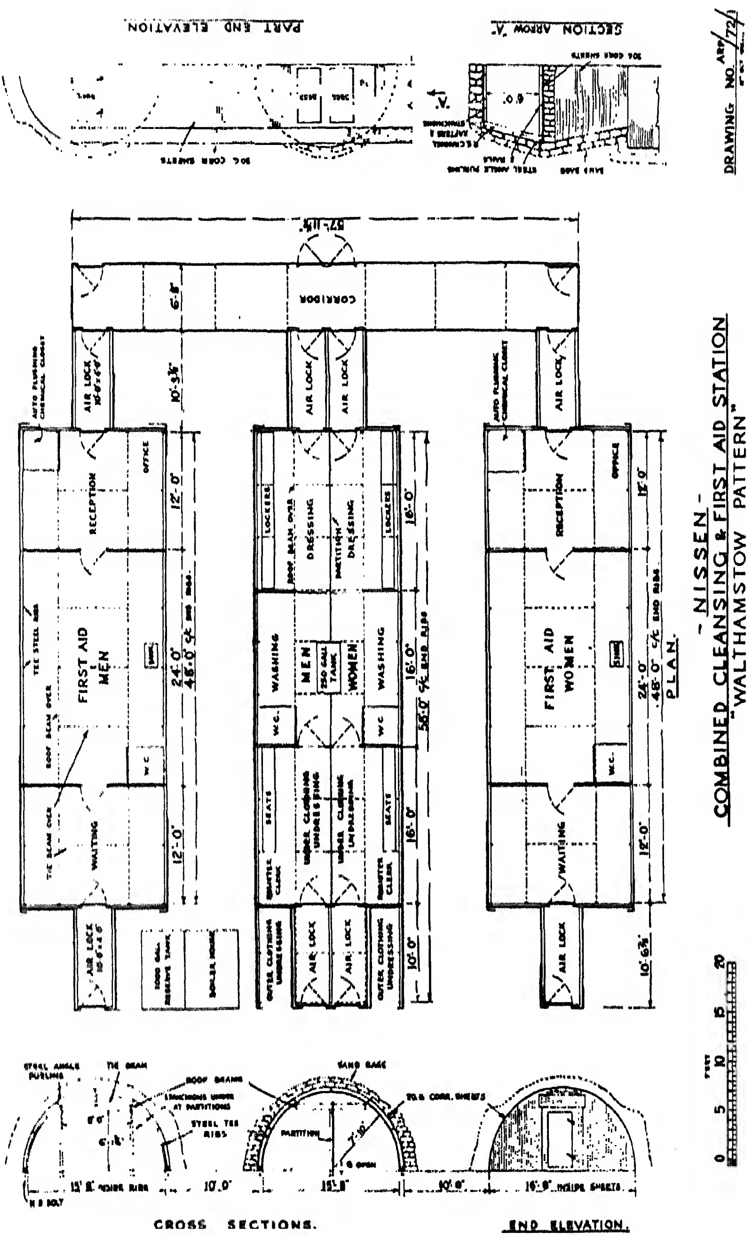


FIG. 288.—Showing above-ground combined cleansing and first aid station, approximate cost, £1,50

centre is shown in Fig. 287, and the minimum staff for the working of it is shown in Table CVIII.

The local authority is responsible for the evacuation of casualties from the factory first aid post to hospital.

It is unnecessary for factories employing 500 workers or less, as a maximum, on the premises at any one time, and *located in a town,* to provide themselves with a first aid and cleansing centre as indicated in Fig. 287. Casualties in such factories can be dealt with in the existing first aid room and further treatment, both as regards first aid and cleansing, should be obtained at the nearest first aid and cleansing centre of the local authority.

(*c*) *First Aid Parties.* These should consist of parties of four trained first aid personnel in protected accommodation distributed over the factory and amongst the bulk of the personnel who are in protected accommodation.

Their duty is to deal with local casualties in the area to which they have been allotted. They will require to be equipped with one first aid haversack and two stretchers per party, and one pouch per person. (Tables CIX and CXI).

(*d*) *Fire Fighting Squads and Fire Watchers.* Fire fighting squads will require to be organised in day and night reliefs, whether night work is being done or otherwise. They should be placed within or in the vicinity of their equipment, both personnel and equipment being provided with protected accommodation, usually a fire station.

(For detailed information see A.R.P. Handbook, No. 9, Incendiary Bombs and Fire Precautions.)

Fires caused by incendiary bombs are best dealt with at their inception. For this reason a network of fire-watching parties should be distributed throughout the factory, their numbers being increased where fire risks are high.

These parties consist of three persons with their equipment located in protected accommodation, usually sited in the corners of buildings and best constructed with sandbags.

The limiting factor is their range of vision, and therefore sectors allotted to fire-watching parties should overlap.

(*e*) *Rescue and Salvage Squads.* These squads require to be organised in day and night reliefs, whether work is being done at night or otherwise. They should be located with, or in the

vicinity of, their equipment, both personnel and equipment being provided with protected accommodation.

Personnel extricated from under *débris* will invariably require medical attention. A first aid party should be included in the rescue and salvage squad.

In large factories, suitable vehicles should form part of the equipment of squads for the speedy transport of both personnel and equipment to wherever required.

(*f*) *Decontamination Squads.* Decontamination squads, which will include personnel for searching the factory premises for gas-contaminated areas, should be located in protected accommodation, with or near to their equipment. If possible, each squad should be situated in the area for which it is responsible.

Each area thus allotted should be again sub-divided, each sub-division being made the responsibility of a particular gas searcher. By this means an area is quickly and effectively searched for gas contamination.

(*g*) *Key Men.* Key men are those who must remain during the progress of an air raid to attend such duties as turning off gas, electricity, attending to boilers, and similar work, and they can be incorporated with the nearest fire-watching party. If this is not feasible, protected accommodation, usually constructed with sandbags, must be provided.

Key men should be posted in pairs, and if possible, in threes ; or a key man should have one or two men with him and not be posted singly.

3. Intercommunication

(*a*) *Warning System.* It is necessary that the means of INTERNAL warning should be frequently tested. Where EXTERNAL warning is given by telephone or by sound, it is important that the listener who receives it should be able to operate at once the INTERNAL warning signal of a factory so that all employees may obtain as early warning as possible.

(*b*) *External and Internal Communications from A.R.P. Control Post.* It is important that communications from the control post to the local authorities be maintained at all times.

In cases where the factory telephone exchange is evacuated, alternative telephone communication should be arranged

with the local authority by means of a by-pass line cutting out the factory telephone exchange. A messenger service should also be organised.

For the maintenance of control, communications between the control post and the A.R.P. services and personnel in protected accommodation is essential.

The various means of arranging communication are: Utilising as far as is possible existing post office and house telephone systems, installing field telephones, and arranging a messenger service from the control post to all concerned. Two means should also be arranged, the messenger service being one of them.

4. Buildings and Plant

General Rule. It is obviously impracticable to give the standards of lateral and overhead protection to all plant, and the responsibility for classifying what is vital or otherwise rests with the expert on the spot. After decision on the various vital installations, the standard of lateral protection up to at least the height of the vital plant to be protected and the standard of overhead protection must be applied.

5. Fire

It is essential that every factory should be able to rely on its own resources both as regards fire-fighting equipment and water.

It is most important that an alternative and preferably an independent supply of water should be provided for fire-fighting purposes. Storage tanks sunk in the ground provide a suitable alternative for this purpose. In most cases a pump with booster apparatus and requisite hose is recommended.

Fire watchers must also be provided with adequate equipment for dealing with incendiary bombs at their inception.

6. Lighting

(*a*) *Obscuration of Light* (see Chapter XIV.). No lighting visible externally after dark will be allowed during wartime.

(*b*) *Emergency Lighting.* A system of directional and/or pilot lights will be necessary inside the building, arranged by means of independent batteries, or even oil lamps.

Independent lighting (battery, oil or candle) must also be provided in all A.R.P. accommodation.

7. Alternative Sources of Supply (Electricity, Gas and Water)

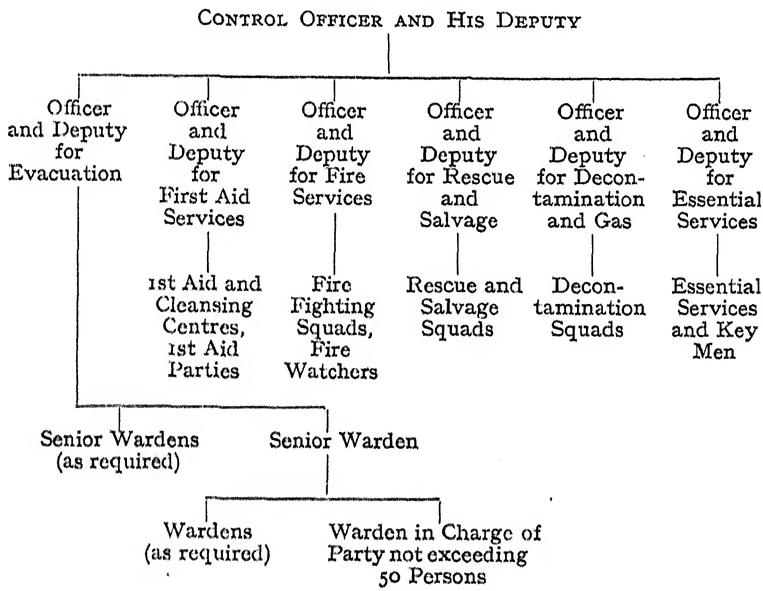
(*a*) *Electricity and Gas.* In factories where electricity or gas or both are vital to production, and if their provision is within reasonable financial limits, an alternative, or preferably an independent supply, should be arranged. Mains should be widely separated.

(*b*) *Water.* This service is often vital to certain processes, and therefore the importance of an alternative supply is stressed.

General Organisation

A suggested layout of an organisation is given below :—

TABLE CVII



Note. A Senior Warden should control about six shelters accommodating approximately 300 persons.

1. Protection to Personnel

This is dealt with in Chapters VI to X.

2. Provide Accommodation for the Protection and Operation of A.R.P. Services.

3. Intercommunication

(i.) Arrange an efficient system of internal warning.

(ii.) Organise a personnel for a twenty-four hour service to receive the air raid warning, and to operate the internal warning.

(iii.) Arrange by-pass line from control post to main exchange line, cutting out factory telephone exchange.

(iv.) Utilise existing factory telephone system and/or field cable to communicate from A.R.P. control post to A.R.P. services, personnel other than A.R.P. services and special localities.

(v.) Organise a messenger service to duplicate means of communication.

4. Buildings and Plant

(i.) Provide lateral protection for vital buildings and vital plant against 500 lb. H.E. bombs falling 50 ft. or more away.

(ii.) Provide overhead cover to vital plant against falling *débris*, 2½ lb. incendiary bombs and damage from broken glass in roof-lights.

Decide what buildings and plant are to be protected and method to be employed in each case.

5. Fire

Considerations.—(i.) Examine buildings and list special fire risks, including attics and inflammable roofs susceptible to incendiary bombs.

(ii.) Examine neighbouring buildings and their possible fire risks to the factory.

(iii.) Consider best means for combating the above fire risks.

(iv.) Divide areas where necessary into sectors for location of fire watchers.

(v.) Consider existing sources of water supply and investigate alternatives.

(vi.) Consider augmentation of existing fire parties and number required for A.R.P. fire-fighting squads and fire watchers.

(vii.) Consider augmentation of existing fire equipment and provision of appliances for dealing with incendiary bombs.

(See A.R.P. Handbook No. 9, Incendiary Bombs and Fire Precautions.)

6. Lighting

(i.) Prevent any lighting being visible externally after dark.

(ii.) Provide the minimum but sufficient internal lighting to enable the evacuation of buildings to protected accommodation being carried out in a speedy and orderly manner.

(iii.) Provide independent lighting in all protected accommodation.

7. Alternative Sources of Supply of Electricity, Gas and Water

(i.) It can be envisaged that repairs to the distribution system will be carried out with reasonable speed.

(ii.) Ring mains, although far superior to single mains, cannot be considered as alternatives if from one source only.

(iii.) The sources of supply from public companies should be thoroughly investigated.

8. Camouflage

No standards can be laid down ; each building or area must be considered separately.

9. A.R.P. Duties and Equipment.

When final decisions on the above points have been made, the following details, where applicable, will have to be worked out for each portion of the scheme :—

(*a*) The duties of all concerned.

(*b*) The equipment required for all the various A.R.P. services and arrangements for its storage.

(*c*) The work to be done, with details of method and material :—

(i.) Now.

(ii.) In the last twenty-four hours.

10. Evacuation to Protected Accommodation

The most careful and detailed preparations and rehearsals will be necessary for efficient working.

Traffic control will be most important to ensure speedy evacuation and prevent congestion at any particular point. Traffic routes must be laid down and directional signs will be found useful to direct personnel.

It is essential that each employee should know his appointed shelter and the route to it, both by day and night.

It is considered that the dispersal of employees to their homes should be discouraged.

NOTES ON CONSTRUCTION OF A BELOW-SURFACE FIRST AID POST AND CLEANSING CENTRE. See Fig. 287.

1. Excavation to be 6 ft.

2. The whole construction must be gasproof, and all entrances and exits must be provided with air-locks.

3. All entrances, exits, and doorways must be made suitable for the passage of stretchers.

4. Equipment must include picks and shovels to excavate occupants if buried.

5. Material used, either precast concrete or steel. First aid rooms can be of hollow wall blocks.

6. Gas filtration plant is not contemplated, but all shelters will be provided with ventilation outlets which are gasproof, but which can be opened up in peace-time, and in case of necessity in war-time.

7. A mound of earth at least 2 ft. above the height of the shelter entrance, minimum 2 ft. 6 in. thick at the top, must be erected at every entrance and exit as a protection against blast. Care must be taken to erect the mound so as to allow the passage of stretchers.

8. Personnel who are contaminated and lightly wounded or unwounded should be admitted at Entrance A. Severely wounded personnel should be admitted at Entrance B, and arrangements must be made in the reception room for keeping the contaminated clear of the uncontaminated.

9. The weatherproof sheds where contaminated personnel should take off and leave behind their contaminated clothing are not shown in Fig. 287.

10. The estimated cost includes excavating and filling back,

cost of material, floor, and erection, but does not include cost of installations, drainage or equipment.

TABLE CVIII

7 ft. sections in concrete or steel	£6	per yard run.
14 ft. 6 in. sections in steel	£14	" "
14 ft. 6 in. sections in concrete	£18	" "
14 ft. 6 in. sections in hollow wall blocks	£28	" "

Estimated cost, including Ramps, Entrances and Exits :—

Concrete or steel	£1,350
Hollow wall blocks	£1,600

The minimum staff required for the working of the First Aid Post in respect of one sex only is as under :—

In charge of post	1
Reception for clean	1
Reception for dirty (contaminated)	2
Washing	2
First aid treatment	3
Recording clerks	2
Stretcher bearers working any 1 pair Reception to First Aid and 1 pair from First Aid to Waiting	4
	15

An economy of personnel according to circumstances is suggested as follows :—

Reduce in charge of post	1
Reception for dirty (contaminated) to	1
Washing to	1
Clerks to	1
Total	4

TABLE CIX SUGGESTED SCALE OF PERSONAL PROTECTIVE EQUIPMENT

This scale is estimated on the basis that a factory is organised for work in two shifts. Separate respirators, steel helmets and eyeshields should be issued to each man of each shift and all other protective equipment transferred from shift to shift.

Example. Fire fighting squads in two shifts, each consisting of 8 men. Total C.D. Respirators in possession, 20 (16 in use, 4 in reserve), total light trousers in possession, 12 pairs (8 pairs in use and 4 pairs in reserve).

Where large numbers are involved, it may be found possible to effect reductions in the scale.

A.R.P. Service.	C.D. Respirators.		Steel Helmets.		Protective Clothing. Light Jackets.		Protective Clothing. Light Trousers.		Protective Clothing. Gloves.		Hoods.		Curtains.		Gum Boots.		Mittens.		Eye Shields.	
	Per Man.	Res.	Per Man.	Res.	Per Man.	Res.	Per Man.	Res.	Per Man.	Res.	Per Man.	Res.	Per Man.	Res.	Per Man.	Res.	Per Man.	Res.	Per Man.	Res.
First Aid Posts or centres	1	25%			0·25	25%	0·25	25%	0·25	25%					0·25	25%				
Cleansing Centres	1	25%			1	25%	1	25%	1	50%					1	50%				
First Aid Parties	1	25%	1	10%	1	50%	1	50%	1	50%			1	25%	1	50%			1	100%
Decontamination Squads (including Gas Searchers)	1	50%	1	10%	1	100%	1	100%	1	100%	1	50%	1	25%	1	100%	1	200%	1	100%
Rescue and Salvage Squads (if employed)	1	50%	1	10%	1	100%	1	100%	1	100%			1	25%	1	100%	1	200%	1	100%
Fire Fighters	1	25%	1	10%	1	50%	1	50%	1	50%			1	25%	1	50%			1	100%
Fire Watchers	1	25%	1	10%	1	50%	1	50%	1	50%			1	25%	1	50%			1	100%
Telephone Operators	1																			
Messengers	1		1		1		1		1				1		1					
Key Men	1	25%	1	10%	1	100%	1	100%	1	100%			1	25%	1				1	100%
*Warden Services	1	25%	1	10%	0·5	50%	0·5	50%	0·5	50%			1	25%	0·5	50%			1	100%

* 1 Warden to each 50-person shelter.

Res. = Reserve per man.

TABLE CX

A.R.P. PERSONNEL

Table giving numbers that are suggested as a basis, and intended for modification to suit individual cases.

The figures for *Fire Watchers* and *Key Men* should be taken as very approximate, and each factory must consider them in relation to its own requirements. If more than one shift is employed the numbers to be trained must be increased *pro rata*.

Duties.	Numbers of Persons Employed.				
	31–500	500	1,000	2,000	5,000
First Aid Post or Centre.			4 (1 × 4)	8 (2 × 4)	12 (2 × 6)
Cleansing Centre (Men or Women)			2 (1 × 2)	4 (1 × 4)	8 (2 × 4)
First Aid Parties (4 persons)		8 (2 × 4)	8 (2 × 4)	12 (3 × 4)	16 (4 × 4)
Decontamination Squads including Gas Searchers			6 (1 × 6)	6 (1 × 6)	12 (2 × 6)
Rescue and Salvage Parties		6 (1 × 6)	12 (2 × 6)	18 (3 × 6)	24 (4 × 6)
Fire Fighters or Group Fire Parties	8 (1 × 8)	8 (1 × 8)	8 (1 × 8)	16 (2 × 8)	24 (3 × 8)
*Fire Watchers . .	3 (1 × 3)	6 (2 × 3)	9 (3 × 3)	12 (4 × 3)	18 (6 × 3)
Telephone Operators .		1	2 (1 × 2)	3 (1 × 3)	3 (1 × 3)
Messengers . .		2	3	4	6
Key Men . . .	As required, Each party consisting of two or three persons.				
TOTALS : At any one time, excluding Key Men	11	31	54	83	123

NOTE. The figures in brackets indicate the number of parties and the strength per party, *e.g.*, (2 × 3) means two parties, each of three persons.

* An alternative method of calculation is to allow at least one party of three for every 8,000 sq. ft. of roof area.

Table CXI

Equipment for a First Aid Party

Suggested Contents: The Pouch

(One Pouch per Man)

Bandages, triangular		9
"Dressing, first aid," large		6
,, ,, ,, medium		6
Canes (for tightening improvised tourniquets) (6 in. long)		3
Labels, Casualty Identity. Book of 15 (with indelible pencil)		1
Ointment, Bleach (and pieces of clean, washed rag), 2 oz. tins	tin	1
Safety Pins, large, cards of	cards	3
Scissors, 7 in., with lanyard (at least one blade pointed)	pr.	1
Tannic Acid Jelly, $\frac{3}{4}$ oz. tubes	tubes	2
Torch, electric, hand, small (blue bulbed)		1
Tourniquets, Samway 1; St. John's type 2		3

(Each member of a First Aid Party should carry a water-bottle.)

Suggested Contents: First Aid Parties' Haversack

(One Haversack per Party).

Bandages, triangular		36
Canes for tightening improvised tourniquets (6 in. long)		8
Clasp Knife, large		1
Cotton wool, 1 oz. pkts.	pkts.	6
Dressings, first aid, large		18
,, ,, ,, medium		12
Lint, unmedicated, in squares about 8 in. × 12 in.	squares	6
Ointment, Bleach, in 2 oz. tins (and clean, washed rags)	tins	4
Safety Pins, large, cards of	cards	8
Tourniquets, St. John's type		
Splints, sectional, wooden	sets	
Straps, webbing, with metal fasteners for securing splints, length about 18 in., width about 2 in.	straps	18
Tannic Acid Jelly, $\frac{3}{4}$ oz. tubes	tubes	4
Torch or Lamp, with stand and shield		1

Note. The above list replaces the list given in A.R.P. 6, Appendix J.

Example of a Works A.R.P. Scheme

TABLE CXII

(1,000 Employees)

OUTLINE OF SCHEME

Section.	Duties.	Name of Responsible Officer.	Names of Deputies.
1. *Organisation* .	Planning organisation prior to an emergency.	A	I J
2. *Control* . .	Controlling all personnel and A.R.P. activities during an emergency.	B	K L
3. *Dispersal* .	The equipment of the shelters and arrangements for the dispersal of employees to the shelters.	C	M N
4. *Observation* .	The manning of selected look-out posts and arrangements for sending reports by telephone or messenger to headquarters.	D	O P
5. *First Aid* .	Equipment and manning the first aid posts and the supply of first aid equipment and personnel to shelters. Also equipment and personnel for cleansing persons contaminated by gas.	E	Q R
6. *Fire Fighting* .	Organisation of fire fighting services, including equipment and personnel.	F	S T
7. *Gas Detection* .	To arrange disposition and operation of gas detection equipment and personnel.	G	U V
8. *Essential Services*	Organisation of essential services, personnel and equipment, including rescue, demolition and decontamination of material.	H	W X

Prior to an Emergency

Section I

The general organisation of the scheme prior to an emergency and the planning and construction of all shelters, watchers' posts, aid posts, fire stations, cleansing centres, etc., is in the

hands of Mr. A. with the assistance of Mr. Y. on the supply of equipment, Capt. Z. on the training of personnel, Mr. AA. being chief instructor and Mr. BB. the A.R.P. storekeeper.

On Declaration of State of Emergency

The staff already warned of their special duties will at once attend to the following points and report when completed.

(1) Move records to war-time protected store.
(2) Test through all emergency telephone, signal and emergency lighting arrangements.
(3) Fill all reserve water tanks.
(4) Run and test auxiliary power plants.
(5) Mobilise all A.R.P. personnel.
(6) Issue all war-time stores.
(7) Distribute all first aid and cleansing stores, protective clothing, etc.
(8) Check over all nominal rolls and operation instructions.
(9) Check over all routing indicators.
(10) Bring into force all light obscuration arrangements.
(11) Clear all passages and roadways of all unnecessary obstructions.
(12) Carry out a general rehearsal.

During an Emergency

Section II Control

The control headquarters are situated in the underground shelter A_1, opposite to the main entrance to the offices, see site plan, No. 4913 (Fig. 289).

Reserve headquarters is situate in shelter No. D_3 behind the A.R.P. stores. The factory is divided into Sections A, B, C and D, each with five 50-person shelters conveniently situated.

Standing Orders

(1) Immediately on receipt of an air raid warning the chief telephonist will set into operation all the works warning signals, switch over the telephone lines to the switchboard in the control headquarters and take up her position there.

(2) The personnel enumerated below will then proceed to

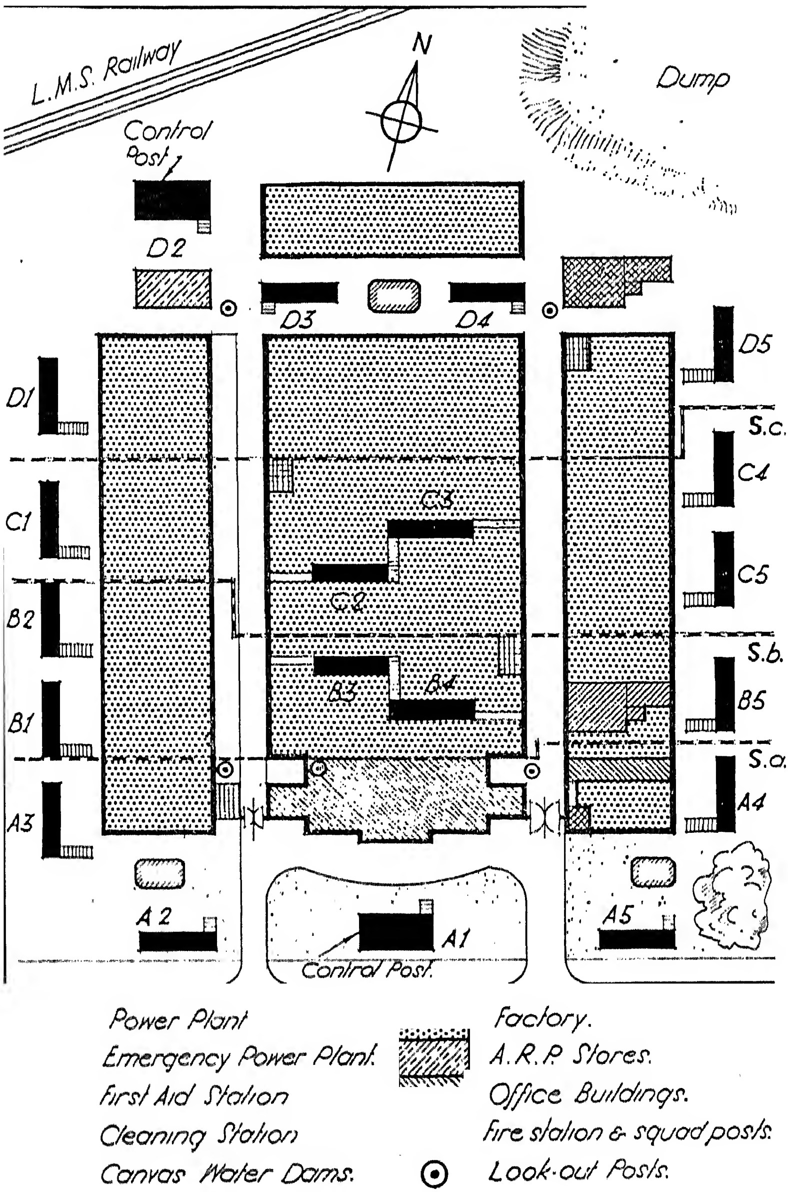


FIG. 289.—Plan of factory showing A.R.P. organisation and situation of shelters.

control headquarters and remain there on duty until the "all-clear" has been received and the chief control officer is satisfied that all shelters have been evacuated and emergency work completed.

(3) The control officer will at once ensure that dispersal to shelters has been successfully accomplished and that all observers and emergency squads are at their posts.

(4) Control headquarters will keep in touch by telephone or runner with shelters, look-out posts and emergency squads, and keep a careful log of all messages received and action taken thereon.

(5) Headquarters will take appropriate action through the factory emergency services immediately any casualties and/or damage may be reported.

(6) Report all air raid "incidents" affecting the factory

TABLE CXIII

PERSONNEL

	Control Headquarters.		Reserve Headquarters.
Chief control officer	Mr. B.	...	Mr. L.
Deputy	,, K	...	—
Dispersal officer	,, C	...	,, M
Deputy	,, N	...	—
Gas detection officer	,, G	...	,, U
Deputy	,, V	...	—
Telephonists	2	...	2
Messengers	2	...	2
Staff, sheltering	40	...	43

EQUIPMENT

	No.		No.
Plans of factory layout showing all shelters and sectional areas	1	...	1
Location diagram for equipment and emergency services	1	...	1
Lists of all A.R.P. personnel and where located	1	...	1
Sets of report forms and control log book	1	...	1
Table, chairs and stationery cupboards . sets	1	...	1
Cupboard for protective clothing and masks for gas detectors	1	...	1
Gas detectors	1	...	1
G.P.O. telephone switchboard and 2 instruments	1	...	1
Field service telephone switchboard and 2 instruments	1	...	1
Telephone directory and separate list of important numbers	1	...	1
Wireless set	1	...	1
Set of fittings and equipment as for all shelters (*infra*)	1	...	1

premises to the town A.R.P. headquarters and call for outside assistance from the town A.R.P. services if necessary.

(7) Without hesitation headquarters will take any action that conditions render desirable to safeguard life and the property of the firm.

(8) Headquarters will ensure that it is safe to leave the shelters before permitting personnel to do so.

(9) Reserve headquarters will be in constant telephonic communication with control headquarters and will listen in on all reports and orders so as to be ready to take over immediately control headquarters is unable to continue.

Section III. Dispersal

Notes. The protection of employees during air raids is ensured by the provision of twenty buried shelters, each for fifty persons, arranged in four groups as shown on the plan.

Employees of both sexes will occupy shelters by departments under their own charge hands and foremen. Each employee will have an allotted place in a particular shelter and will wear a badge indicating his shelter number, while in the works. Each shelter is in the charge of a shelter warden and an assistant.

Air raid warnings will be by intermittent blasts on works klaxons.

Standing Routine

Immediately on receipt of the air raid warning—

Employees will (*a*) stop their particular machines and turn off any service they happen to be utilising—water, compressed air, steam, gas, oil service, electricity, etc.

(*b*) Take up their gas masks and *walk* to their shelters by the appointed routes.

Shelter assistant (if not at the shelters) will *run* to them to open entrances, turn on lights and check employees entering against the nominal roll.

Shop foremen will pass to their shelters after the employees have left the works and after they have ensured that all plant is shut down.

Departmental first aid staff will proceed to their appointed places and report to their A.R.P. chiefs.

A.R.P. duty personnel will proceed to their posts and report present to headquarters by telephone.

No person will leave his shelter until instructed to do so on the order of headquarters.

No smoking in shelters is permitted.

Note. Prominently exhibited in each department of the works is a list of group areas, shelter numbers and names of shelter wardens and assistants.

At least two persons of each sex trained in first aid are allotted to each shelter.

Equipment

Each shelter will have the following equipment :—

Benches for fifty persons.
Electric light (from battery in separate shelter).
Haversack of first aid requisites.
Air supply by manually-operated fan.
Two chemical closets and two buckets.
Water in four two-gallon cans.
Cupboard containing :—

- Box of biscuits.
- One dozen paper drinking cups.
- Two tin bowls.
- Two towels.
- Electric torch.
- Two candles.
- Box matches.
- Six packs of cards.
- One mouth organ.
- Few magazines.
- Six knee game boards.
- Small chemical extinguisher.
- Spade and crowbar.

Section IV. Observation

There are five observation posts. One on the roof of the office building, commanding a view of the whole factory and one at each end of each service road.

All posts are connected by telephone to the control head-

quarters, which in turn is connected to the fire station and emergency posts.

Standing Orders

On receipt of an air raid warning all observers will take their gas masks to their posts, don their steel helmets and report present by telephone to headquarters.

All unusual happenings observed will at once be reported to headquarters control.

Each post will be manned by an observer, an assistant and a runner.

Section V. First Aid

The first aid post adjoins the cleansing station on the east approach to the factory and is equipped to deal with both sexes.

Personnel

First aid post.

In charge . .	Dr. . . . .
Staff . . .	Mrs. . . . .
	Miss. . . . .
	Miss. . . . .
	Mr. . . . .

Cleansing Centre

	Mrs. . . . .
	Mrs. . . . .
	Mr. . . . . and Mr. . . . .

First Aid Parties

A party : Four persons.
B party : Four persons.

Equipment

First aid haversacks will be issued to each party and there will be one in each shelter and in the fire station.

Each man in the first aid parties will have a first aid pouch (for contents see Table CXI).

Section VI. Fire Fighting

The factory emergency fire-fighting personnel will be located as below :—

Squad	Number	Post
1st squad	8	Fire station
2nd ,, ...	3	Section B
3rd ,, ...	3	,, C
4th ,, ...	3	,, D

Routine

(1) On receipt of an air-raid warning, firemen will man their appointed posts and fire leaders will telephone the fire station when ready for action.

(2) The fire chief at the fire station will then report ready for action to control headquarters.

(3) *Any person* observing an outbreak of fire will telephone headquarters, who will instruct nearest fire squad and notify the fire station.

(4) *Any fire squad* observing an outbreak will at once get into action and report to the fire chief.

(5) Reserve squads will be in protected accommodation at the fire station.

(6) The telephones will be manned continuously.

Equipment

The installed works equipment includes pressure mains, fire boxes and hydrants to reach all parts of the factory, and in the stores department there is a sprinkler installation. Chemical extinguishers and sand buckets are installed to approved scale in other parts of the works.

For A.R.P. purposes the plant has been supplemented by three canvas water dams, a light trailer pump, capacity 120–180 g.p.m. at 80 lb. pressure, and light extending ladders, housed on external walls adjoining service roads.

Firemen's personal equipment will be kept at their station or squad posts.

Section VII. Gas Detection

Personnel

The chief gas detection officer will be situated in headquarters with special gas detection apparatus. The second gas detection officer will be situated in reserve headquarters.

Routine and Equipment

(1) All shelters have gas locks and there is a supply of service gas masks and anti-gas clothing for the emergency squads.

(2) Arrangements have been made for the institution of gas cleansing and a gas decontamination squad has been trained. Decontaminating equipment is arranged for and a supply of bleaching powder is in stock.

(3) In an emergency the gas detection officers will place gas detection plates at various points in the works and at the entrances to shelters.

(4) Special gas detection apparatus will be kept in headquarters and reserve headquarters for use of gas detection officers.

(5) If, during a raid warning, enemy aeroplanes have been overhead, gas detection officers will ascertain that no gas has been dropped, and that all is clear before employees are allowed to leave shelters.

Section VIII. Essential Services

Location

Essential service squads will be stationed in protected posts at the undermentioned positions :—

A.R.P. stores.
Fire station.
Power house.

In addition, firemen will be situated in these posts, so that they will be able to co-operate with each other.

Electricians will be posted in pairs in the switch houses, which are protected.

Notes.

(1) Under the term "Essential Services" are included not only the safeguarding of supply lines of water, gas, electricity, etc., but also the carrying out of any necessary emergency services, such as the rescue of imprisoned persons, demolition of dangerous damaged buildings, and the decontamination of material. The essential service squads therefore include men who have intimate knowledge in rescue, demolition, and decontamination.

(2) On receipt of air raid warning, essential service squads and duty men will go straight to their posts as detailed, and will take such action as regards switching off electric power and shutting down gas mains, etc., as may be laid down.

(3) The three main squads will then report to headquarters by telephone that they are in position and ready for action.

(4) Emergency squads will be notified from headquarters should their services be needed and will then act under their leaders in any way the situation may demand.

(5) Should emergency squads themselves observe a need for their services, they will notify headquarters before leaving their posts to deal with the situation.

(6) Furnace men will be accommodated in the shelter nearest to their boilers, and will, if necessary, leave the shelter to attend to them from time to time.

(7) Emergency squads will act under the direct instructions of Control Headquarters.

Equipment

Equipment for the essential services and emergency squads will be drawn up in detail by the works management.

The equipment is already on the works, and in an emergency will be placed in or near the emergency squad posts. It includes pipe-fitters' tools, crowbars, wedges, shores, jacks, pulley blocks, rope, pick axes, spades and plugging material.

The four extending ladders provided for the fire-fighting services will be available also for the emergency squads.

PROVISION FOR EMERGENCY CONDITIONS IN FACTORIES

Ventilation

Modifications that are applicable in peace time to the normal ventilating arrangements of factory shops would provide valuable safeguards in emergency conditions.

Ventilation in factories which are required to be used during or immediately after a gas attack presents a number of special problems, the principal of which are outlined below.

Natural Ventilation

Natural ventilation depends for its operation upon the temperature difference between the inside and outside of a factory and also upon wind velocity. In summer, when the temperatures inside and outside are nearly the same, it depends almost entirely upon the wind, and the result is largely a matter of chance.

Data as to the extraction produced by roof ventilators of various design and under various velocities and temperature differences are obtainable from the makers of these units. The sizes range from 6 in. to 50 in. in diameter. Where roof extraction is provided some form of inlet is normally arranged at a low level in the side walls. These often take the form of ventilators behind radiators under the windows and the size is commonly 9 in. × 9 in. or 14 in. × 9 in., with an outer grating and an inner adjustable register.

To prevent ingress of poisonous gas into a factory it will generally be found necessary to block up all the ordinary ventilators and to introduce a special intake fan which draws air through a gas purifier and smoke filter.

Attempts at making a factory reasonably gas proof would fail were the extractors in the natural ventilation system located too low. Indeed, for the efficient functioning of such a system, the extractors should be at the highest points and the inlets at the lowest points. The intake fan should have a capacity greatly in excess of the normal capacity of the extractors, with the object of producing, if possible, a plenum within the factory, so as to minimise the in-leakage of gas from the exterior.

Mechanical Ventilation

(*a*) *Extract Systems.* Where the problem is one of removing smells, steam, smoke or noxious fumes, extract ventilation is normally provided, and two such systems are indicated in Figs. 290 and 291. The only satisfactory way of dealing with such systems is to insert in the intake chamber a large gas purifier and smoke filter, coupled to an intake fan of sufficient capacity to keep the interior of the factory under a slight pressure above the normal atmospheric pressure.

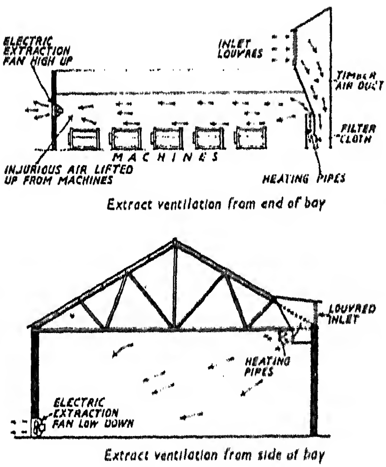


FIG. 290.—Extract ventilation in factories.

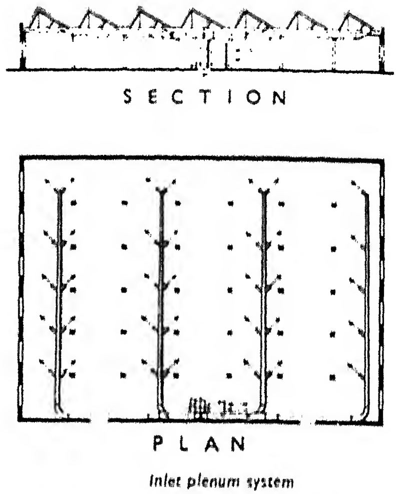


FIG. 291.—Mechanical ventilation in factory by means of inlet plenum.

Where positive extraction is employed it will normally be desirable to shut down the extract system entirely and to rely upon leakage of air through the structure owing to the increased pressure in the interior, thus greatly minimising the danger of ingress of poisonous gases from the outside.

(*b*) *Inlet Systems.* An inlet system is one in which air is delivered into the room or building, being warmed in winter and generally filtered or washed; such a system is illustrated in Fig. 291, which gives a typical arrangement of a plenum overhead ventilating system.

Such a system, with no positive means of extraction, is usually

confined to the warming and ventilation of large spaces such as factories, for which purpose it is one of the cheapest methods. It is usually designed to give not less than four air changes per hour and the ingoing air temperature is normally limited to 120° F. The air heater batteries may utilise steam, hot water, gas or electricity, but for economy of fuel in winter a re-circulation damper is generally included, by means of which the air from the building can be returned for reheating.

Purifiers and arsenical smoke filters should be inserted in the fresh air inlet ducts, in order to ensure that the new supply of air admitted into the interior is free of poisonous fumes.

(*c*) *Combined Inlet and Extract Ventilation.*—In all cases where vigorous ventilation is especially desirable in any particular industry, a combination of mechanical inlet and extract ventilation is normally adopted; such cases include cinemas, theatres, large assembly halls, and factories in which the occupancy is concentrated. The volume of air per occupant is often laid down by the licensing authority; thus the L.C.C. call for a minimum of 1,000 cu. ft. per hour per occupant in places of entertainment, but frequently double this amount may be necessary where noxious fumes are produced in a factory. The air is normally first drawn through a washer which serves the dual purpose of cleaning or washing and of introducing a certain amount of additional moisture when occasion demands.

For use in an emergency a gas purifier and smoke filter should be inserted so that the air entering the factory is free of poisonous fumes. The extraction fan connected by duct work to the extraction grilles generally handles 75 per cent. of that introduced by the plenum plant, the surplus escaping by means of exits, etc.

During an emergency when a gas attack may be expected, it would be desirable to shut down the extract plant altogether, and rely upon the escape of the vitiated air through the air leaks in the structure itself. On the other hand, extraction of fumes over machines may have to be continued, and in this case it may be desirable to increase the capacity of the inlet fans.

Each case requires to be dealt with on its own merits, and a special gas filtration expert should preferably be employed.

(*d*) *Air Conditioning.* Air conditioning is a highly specialised form of ventilation, involving the provision of the desired

temperature and humidity in the atmosphere in factories. In certain industries air conditioning is essential. It may comprise an air washer and the humidifier in which the air supply is washed in sprays of water, the free moisture being removed by eliminator plates; a preheater and a main heater by which the air is warmed in winter, the former being before and the latter after the washer; a fan for delivering the air to the building through ducts, and a second fan for removing the exhaust air. Humidifiers may be employed in the main system or locally as the particular industry demands, but in each case under emergency conditions when a gas attack is to be expected the gas purifiers and smoke filters should be introduced into the circuit at the inlet of fresh air to the system. Extractions should be slowed down or stopped altogether if this is possible, in order to ensure a definite plenum within the building.

Boiler Plants

In boiler plants, where a considerable amount of air is required for combustion in the furnaces, special problems arise.

(*a*) *Natural Draught.* Stokers who are required to attend the operation of boiler plants during or immediately after a gas attack should be provided with blast and splinter protection as indicated on pp. 38, 211 *et seq.* They should also be provided with gas masks of the most efficient service pattern and, as the natural draught into the boilers causes a very considerable inrush of air into the stokehold from the outside, special provision should be made to seal up all the normal inlets and to substitute for them a large intake fan which will be provided with gas purifiers and smoke filters. Its capacity should be at least 50 per cent. higher than that normally required for combustion purposes in order that there may be a definite plenum in the stokehold. This will also, of course, involve careful adjustment of dampers in order to provide proper conditions for combustion in the furnace.

(*b*) *Induced Draught.* In the case of induced draught being used, the same problems arise, but perhaps the difficulties are aggravated. The only safe method is to use a large intake fan to deal with the ventilated air for the stokehold and also the

air required for combustion, adjusting the speed of the extract fan to suit the new conditions. It is always desirable to have a plenum in the areas to be occupied by personnel in order to minimise the inleakage of gas.

(*c*) *Forced and Induced Draught.* When both forced and induced draught are combined in modern boiler plants it would be desirable to ensure in every case that the forced-draught fan draws in supplies of fresh air from the exterior by means of trunking. The stokehold can then be independently ventilated by an inlet fan provided with gas purifiers and smoke filters so as to create a small plenum in the stokehold.

Explosives

Explosive materials used in factories, such as raw materials used in the manufacture of cellulose paints, mixtures used in the capping of matches and other explosive substances, should preferably be stored underground in isolated protected buildings. The roofs should be such as to prevent the penetration of incendiary bombs and, where necessary, explosion vents in the form of light timber glazed lantern lights should be installed with a view to permitting the harmless escape of the products of combustion in the event of an explosion or of fire.

The precautions usually adopted in the storage of films in film studio premises could well be adopted for the emergency storage of explosive materials, but the policy of having the minimum amount of material in process should be followed rigorously with a view to keeping the main storage as remote as possible from occupied buildings.

Fuel Oil Storage

The same remarks apply to the storage of fuel oil, which should be in bulk underground in protected accommodation as remote as possible from the heating furnaces or process equipment in which it is used. Oil pipelines leading from the bulk stores to the small cistern usually installed near the places of distribution should of course be protected as outlined below and provided with isolating valves, which can be quickly shut off on receipt of an air raid warning.

Inflammable Gas

Escapes of inflammable gas, such as coal gas, hydrogen or other mixtures used in manufacturing processes, are obviously a source of danger and might result in explosions were the supply from the main storage not cut off immediately. Here again the main storage should be arranged to be as remote as possible from the occupied buildings, and as gas holders are not easily constructed below ground, in protected premises, it might be desirable immediately on receipt of an air raid warning to allow the material harmlessly to escape, thus minimising the danger on the commencement of a raid.

Domestic Fires, Industrial Furnaces, etc.

On receipt of a warning it is desirable always to quench all domestic fires and furnaces used in industrial operations, as if they are allowed continuously to burn they induce dangerous currents of air up the chimney, thus creating a depression in the atmospheric pressure in the inside of the building and drawing in any poison gas that may be in the vicinity. Apart from this the danger of fire in partial demolition of the building is materially increased, especially where the roof or flooring construction over is in timber or similar inflammable material.

Steam Services

It is obvious that high pressure steam services are very vulnerable to damage and if damaged might cause serious confusion and injury, if not a dangerous explosion. On receipt of a warning, all supply stop valves should be shut down in the boiler house and measures taken immediately to reduce the pressure on the boilers without blowing of large volumes of free steam into the atmosphere if this can be avoided.

Methods of protecting steam plants and distribution pipe lines are dealt with hereafter.

Petrol

In factories, where it is customary to store small local supplies of petrol in tins it is desirable to introduce the bulk system of storage in underground tanks, constructed in accordance with the regulations.

Except in the case of a direct hit or of leakages caused through earth tremors such tanks do not present any undue hazards, but it is undesirable to site underground shelters near them.

Stores of Acids

In industrial plants it is not uncommon to store acids in carboys in various open spaces immediately adjoining the workshop. Such a practice should be discontinued and the concentrated acids should be placed in fireproof stores, so sited that in the event of the carboys being broken the acid would not flow by gravity to any position where it may be a source of danger, such as into a shelter, or across a roadway or passage.

Buildings in which dangerous acids are stored should, therefore, be surrounded by a paved concrete area with a raised kerb all round, providing a container of sufficient depth to hold the complete storage of the corrosive liquid.

Dangerous Materials

Dangerous materials like ammonia and SO_2, used in refrigeration plants, and inflammable materials, like benzine, used in dry cleaning plants, and oil used in paint manufacture should be protected similarly.

High Tension Electric Supplies

In many establishments in this country the electric supplies are taken from the extra high tension cables which pass overhead to transformers established on the premises. It is obvious that such exposed high tension wiring is a source of danger, especially when there is possibility of water being sprayed on to a fire. In such cases it would be desirable to arrange with the electric supply company, where possible, to divert the extra high tension cables or to arrange for the section to be completely cut out in the event of an emergency.

Electric supplies from private generating stations in the factory premises are more easily controlled and the precautions to be observed are dealt with elsewhere.

There is no doubt that it is preferable to install a stand-by emergency plant, and this should have a capacity sufficient to deal with essential services in the factory and should of course

be located as far remote from the normal generating station as the exigencies of the site will permit.

Motor Transport Vehicles

The planning of an industrial garage in close proximity to the occupied buildings is not unusual, and where such an arrangement exists it will be desirable to empty all petrol tanks to an underground bulk storage when the vehicles are parked. In the case of new factories, of course, the garage which normally has hazardous fire risks should be located as remote from the manufacturing premises as is convenient.

Water Supply

There is no doubt that in major operations in the air involving attack on civil communities and industrial establishments there will be a phenomenal demand upon water supplies for fire fighting purposes. Sprinkler installations with alternative sources of supply from overhead tanks are very vulnerable to damage from air raids and water pressure on mains is likely to be seriously affected by the demand in the neighbourhood. For that reason it is desirable that a large reserve supply of water is arranged for and where possible the installation of automatic and chemical fire extinguishers should be arranged on the maximum scale.

PLANT PROTECTION

The "splinter-proofing" of vital plant in factories during aerial bombardment is of the greatest importance if production is to be resumed without inordinate delay apart from direct hits.

Hazards arising in aerial attacks are set down in the table LXVIII on p. 240 in ascending order of importance and severity. The table also indicates the various degrees of protection, how they can be obtained, and the approximate ranges of cost per person accommodated.

The protection of power plants, generating stations and vital services in industry against direct hits involves in most cases a prohibitive expenditure of capital, and would involve the almost entire reconstruction of power houses. It is much more difficult

to prescribe satisfactory measures for existing plant than to design an entirely new one. To secure protection for new plant against the hazards of aerial bombardment, the usual spacious arrangement accommodated in a lofty building of normal construction would have to be replaced by an exceptionally compact layout, accommodated partly underground or at least covered with a strong reinforced concrete structure preferably of parabolic arched construction or conical in shape.

A convenient arrangement would be to use two shells of reinforced concrete, the space between them being utilised for the accommodation of auxiliary water tanks, storage of coal, air passages, connecting galleries, etc.

The construction of barrier walls at frequent intervals throughout the plant would be necessary to localise the damage from direct hits. The entire omission of windows would also be a necessary condition and the use of artificial light and forced ventilation would therefore be essential.

The whole problem is beset with many difficulties, because auxiliary items of plant, such as draught fans, mechanical stokers, pumps, etc., would need to be duplicated and located in positions as remote as possible from each other, so that in the event of one being put out of action the standby plant could be utilised. The provision of bomb shelters for the operating staff is also a necessity.

Remote control of the plant from a bomb-proof shelter is also desirable, but the protection of the plant itself is of considerable importance and presents the greatest difficulty. There is no doubt that most power plants are exceptionally vulnerable to damage from direct hits, but the provision of Class 5 protection is by no means an impossibility. It is usual to place coal bunkers in front of the boilers and not immediately above them, but there is no reason why the latter alternative should not be adopted, as this will automatically provide very considerable protection against splinters and falling fragments of anti-aircraft shell. The safe depth to which the coal can be stored in the bunkers over the boilers would depend mainly upon the choice of fuel. In most cases, however, it would be quite safe to allow for a depth of 20 ft., for there would be little difficulty experienced through the heat from the boilers themselves, providing lagging is suitable and there is a certain amount of

ventilation between the top of the boilers and the underside of the bunkers.

The provision of adequate resistance to the penetration of splinters in new buildings to accommodate vital plant can easily be arranged, but in existing buildings the problem usually resolves itself into the protection of window openings. The construction of sandbagged walls or supplementary walls round the buildings would not be desirable nor necessary, as it would be an advantage to retain the use of the windows until the last moment. For this reason the author recommends the use of mattresses of metal wool, 4 in. thick, hung over the window openings generally as shown in Fig. 270. Blankets made of steel wool, 4 in. thick, weigh about 1 lb. per sq. ft. and may

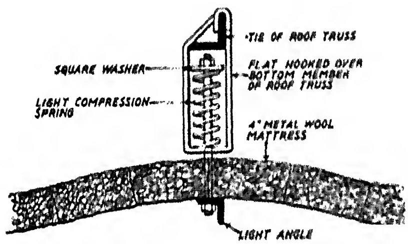


FIG. 292.—Spring suspension for metal wool mattresses festooned over vital plant for protection against fragments of A.A. shell.

be made up and stored against an emergency, so that if the brackets are fixed on the outside of the buildings over the windows as shown on the sketch the mattresses could be hung up in the event of hostilities breaking out.

The fact that the mattresses are hung loosely in front of the window enables them to recede in front of the advancing blast wave and thus stop most splinters impinging upon them. Heavier splinters which may come from a more distant bomb may perforate the mattresses, but experience shows that most of the energy of impact is already spent and the splinters are not so likely to cause damage to vital plant accommodated within the building.

Apart from the provision of solid protection as already enumerated on p. 38, the author knows of no better means of arresting flying splinters than by the use of some such mattress as indicated in Fig. 271. For the same reason the splinter-proof protection of high-pressure boiler plant and electrical

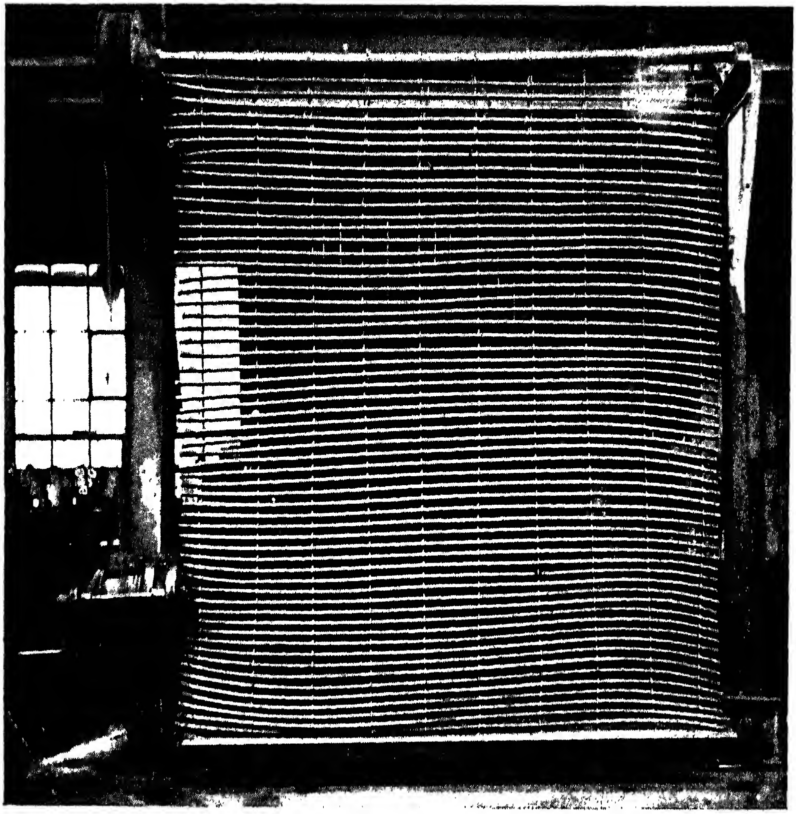


FIG. 293.—Photograph of localising screen of woven wire cables.

(Courtesy R. White & Sons Ltd.)

[*To face page* 646

machines, transformers, etc., can be effected by the use of a covering of mattresses of metal wool attached to roof trusses or the like with spring suspensions, generally as shown in Fig. 292. By this arrangement the metal wool mattresses would festoon between the light angle supports under each of the roof trusses and as these supports themselves are on spring suspension, there would be little or no possibility of getting a splinter or a fragment of anti-aircraft shell through the roof and through the mattresses with sufficient velocity to do any damage on electrical machinery below or on high-pressure boilers.

For interior use steel wool would be satisfactory ; when the mattresses are made up they can be preserved against rusting by dipping them into boiled linseed oil or varnish, which forms an elastic waterproof skin on the fibres of the steel.

LOCALISING SCREENS

For localising the Effects of Bomb or Shell Explosion

(*Patent applied for*)

(*R. White & Sons*)

This is a screen or curtain made of heavy steel ropes laid horizontally, and bound together by flexible vertical ropes, as shown in Fig. 293, which shows a screen 10 ft. sq.

The horizontal ropes may be old colliery winding ropes of lock coil construction, made from solid steel wires throughout, without any hemp core. The individual outer wires are locked together, so that broken strands cannot get loose. They are made of high tensile steel of about 120 tons per sq. in. tensile, thus offering effective resistance to the cutting action of shell splinters, whilst the inertia of the weight of the ropes themselves gives effective damping to shell blast.

When not required each screen is wound up round a steel tube, out of the way.

The weight of a screen 10 ft. square when made from steel ropes 1 in. dia., with spaces of 1 in. between, is about 15 cwt. or 17 lb. per sq, ft.

If made of ropes 1¼ in. dia., with 1¼ in. spaces, the weight would work out to about 22 cwt. or 25 lb. per sq. ft.

If the ropes are 1½ in. dia., with 1½ in. spaces, the weight is about 30 cwt. or 33 lb. per sq. ft.

ESTIMATED COSTS

If made from ¾ in. diameter secondhand Lang's Lay Ropes, with about ¾ in. opening between ropes, with new flexible vertical ropes, ¼ in. diameter, spaced 12 in. apart : 4*s*. 9*d*. per sq. ft. or 4*s*. 3*d*. per sq. ft. for large quantities.

Price per net 10 ft. sq. . .	each	£23	15	0
Or for large quantities . .	,,	£21	5	0

Total weight of screen about 9 cwt., or about 11 lb. per sq. ft.

If made from ⅞ in. diameter secondhand Lang's Lay Ropes, with about ⅞ in. opening between ropes: 5*s*. per sq. ft., or 4*s*. 6*d*. per sq. ft. for large quantities.

Price per net 10 ft. sq. . . .	each	£25	0	0
Or for large quantities. . .	,,	£22	10	0

Total weight of screen about 11 cwt., or about 12½ lb. per sq. ft.

If made from 1 in. diameter secondhand Lock Coil Colliery Winding Ropes, with about 1 in. opening between the horizontal ropes, and New Flexible Vertical Ropes, ¼ in. diameter spaced 12 in. apart: 5*s*. 6*d*. per sq. ft., or 5*s*. per sq. ft. for large quantities.

Price per net 10 ft. sq. . .	each	£27	10	0
Or for large quantities. . .	,,	£25	0	0

Total weight of screen about 15 cwt., or about 17 lb. per sq. ft.

If made from New Lock Coil Guide Ropes, 1 in. diameter : 11*s*. per sq. ft., or 10*s*. 6*d*. per sq. ft. for large quantities.

Price per net 10 ft. sq. . . .	each	£55	0	0
Or for large quantities . . .	,,	£52	10	0

Total weight about 15 cwt., or about 17 lb. per sq. ft.

If made from secondhand Lang's Lay Rope, 1 in. diameter : 5*s*. per sq. ft., or 4*s*. 6*d*. per sq. ft. for large quantities.

Price per net 10 ft. sq.. . .	each	£25	0	0
Or for large quantities . . .	,,	£22	10	0

Total weight about 11 cwt., or 12½ lb. per sq. ft.

If made from 1⅛ in. diameter secondhand Lock Coil Colliery Winding Ropes, with an opening of about 1⅛ in. between the ropes : 6*s*. per sq. ft., or 5*s*. 6*d*. per sq. ft. for large quantities.

Price per net 10 ft. sq. . .	each	£30	0	0
Or for large quantities . .	,,	£27	10	0

Total weight of screen about 19 cwt., or about 21½ lb. per sq. ft.

If made from New Lock Coil Guide Ropes, 1⅛ in. diameter: 12*s*. 9*d*. per sq. ft., or 12*s*. 3*d*. per sq. ft. for large quantities.

Price per net 10 ft. sq. . .	each	£63	15	0
Or for large quantities . .	,,	£61	5	0

Total weight of screen about 19 cwt., or about 21½ lb. per sq. ft.

If made from secondhand Lang's Lay Ropes, 1⅛ in. diameter: 5*s*. 4*d*. per sq. ft., or 4*s*. 10*d*. per sq. ft. for large quantities.

Price per net 10 ft. sq. . .	each	£26	13	4
Or for large quantities . .	,,	£24	3	4

Total weight about 14 cwt., or about 15½ lb. per sq. ft.

If made from 1¼ in. diameter secondhand Lock Coil Colliery Winding Ropes, with about 1¼ in. opening between ropes: 6*s*. 6*d*. per sq. ft., or 6*s*. per sq. ft. for large quantities.

Price per net 10 ft. square . .	each	£32	10	0
Or for large quantities . . .	,,	30	0	0

Total weight about 22 cwt., or about 25 lb. per sq. ft.

If made from New Lock Coil Guide Ropes, 1¼ in. diameter: 14*s*. 2*d*. per sq. ft., or 13*s*. 8*d*. per sq. ft. for large quantities.

Price per net 10ft. sq. . .	each	£70	16	8
Or for large quantities . .	,,	68	6	8

Total weight about 22 cwt., or about 25 lb. per sq. ft.

If made from secondhand Lang's Lay Ropes 1¼ in. diameter: 5*s*. 9*d*. per sq. ft., or 5*s*. 3*d*. per sq. ft. for large quantities.

Price per net 10 ft. sq. . .	each	£28	15	0
Or for large quantities . .	,,	26	5	0

Total weight about 16 cwt., or about 18 lb. per sq. ft.

All delivered F.O.T., Works Sidings, Widnes.

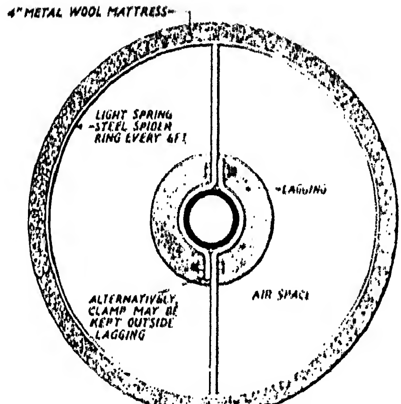
Blast

The protection of vital plant against the effects of blast is a more difficult matter, but if the protecting building is of the reinforced concrete framed design there should be little danger of damage or complete collapse of the building when subjected to blast pressure. The installation of automatic shut-off and isolating valves for use in the event of a sudden pressure drop on the plant side due to failure of pipes, etc., is recommended for consideration as an A.R.P. measure.

In water supplies, burst pipe valves which automatically close in the event of a main suddenly drawing off an abnormal

flow of water should also be installed near the reservoir or pumps, in order to minimise the danger of flooding in the event of damage by bombardment. Buried high-voltage cables become a source of danger in the event of fracture or flooding during a bombardment, but short of constructing specially heavy arched covers there appears to be no ready method of protecting them.

High pressure steam pipes, water mains, etc., carried in the open are very vulnerable to damage by splinters, and the writer therefore recommends the adoption of some such



Mattress protection for exposed pipelines

FIG. 294.—Splinter protection for exposed pressure mains.

arrangement as is shown in Fig. 294. The strength and stiffness of the pipe supports will need consideration before the extra load due to the mattresses is applied and, in the case of steam pipes, the clamp will need, of course, to be kept outside the lagging in order to prevent loss of heat by radiation, which would otherwise be considerable.

Industrialists and engineers in charge of power stations must give serious attention to this matter of the protection of vital plant during aerial bombardment, as in most cases the shutting down of the plant would be nothing more or less than capitulation in advance, the maintenance of the services being vital to the defence of the civil population.

CHAPTER XVI

COSTS OF PROTECTION

It will readily be realised that local circumstances may have a dominating influence upon the cost of providing any required degree of protection for the civil population, but for the convenience of the reader and at the risk of considerable criticism the author gives in Table CXV, on pp. 652 *et seq.*, estimates of cost of the various types of shelter illustrated in this volume.

In arriving at the capacities, both "normal" and "crush," the minimal results of calculations based upon the data given in Table CXIV below for sealed shelters unventilated have been utilised.

TABLE CXIV

Normal Capacities of Sealed Shelters.	*Crush Capacities of Sealed Shelters.*
75 sq. ft. total per person for 3 hrs. —0·86 cu. ft. per person per min.	Occupation for 1 hr.
100 sq. ft. total per person for 12 hrs. —0·29 cu. ft. per person per min.	3½ sq. ft. floor area. —0·2 cu. ft. per person per min. 30 sq. ft. total surface per person.
Normal Capacities of Ventilated Shelters.	*Crush Capacities of Ventilated Shelters.*
6 sq. ft. floor space per person. —150 cu. ft. per person per hour. or 2½ cu. ft. per person per min.	3½ sq. ft. floor space per person. 20 sq. ft. total space per person —1 cu. ft. per person per min.
Open Shelters with Occupants wearing Gas Masks. *Normal.*	*Open Shelters with Occupants wearing Gas Masks.* *Crush.*
6 sq. ft. floor space per person.	3 sq. ft. floor space per person.

Two children under ten years of age counted as one adult.

The estimates of cost have been taken out in detail based upon the ruling prices of labour and material in the London area at the time of going to press, and although local exigencies may influence actual costs, the estimates afford a reasonably safe basis for comparison.

The accommodation is based upon Table CXV and the costs are worked out on a *per capita* basis for the protective

Table CXV

Fig. No.	Accommodation. Normal 3 hrs. A	Accommodation. Crush 1 hr. B	Cost—Complete. Total. £ s. d.	Cost—Complete. Per Capita. A £ s. d.	Cost—Complete. Per Capita. B £ s. d.	Cost—Materials Only. Total. £ s. s.	Cost—Materials Only. Per Capita. A £ s. d.	Cost—Materials Only. Per Capita. B £ s. d.	Remarks.
24	5	7	56 5 0	11 5 0	8 0 9	26 14 8	5 6 11	3 16 8	
25	5	7	22 18 0	4 12 0	3 5 0	—	—	—	
116	—	—	1 11 0	—	—	1 2 0	—	—	Price per yard run.
117 & 118	5·3	12	57 16 0	10 18 0	4 16 0	45 16 0	8 13 0	3 16 0	Outhouse over shelter extra.
119	1	2	12 4 0	12 4 0	6 2 0	6 11 0	6 11 0	3 6 0	Price per yard run. Exits not included.
120 & 121	3·3	6	49 8 0	14 19 0	8 5 0	35 14 0	10 16 0	5 19 0	Gas-proof doors and curtains £15 extra.
124	4	11	175 0 0	43 15 0	15 18 0	—	—	—	Price does not include for lighting.
123	4	11	181 8 0	45 7 0	16 10 0	134 3 0	33 11 0	12 4 0	
126	3	6	53 12 0	17 17 0	8 19 0	41 9 0	13 16 0	6 18 0	
127 A	5	15	36 0 0	7 4 0	2 8 0	—	—	—	
127 B	10	30	62 0 0	6 4 0	2 1 0	—	—	—	
127 C	20	40	87 0 0	4 7 0	2 4 0	—	—	—	
128 S.T.S. 1	6	14	103 2 0	17 4 0	7 7 0	95 3 0	15 17 0	6 16 0	4′ 6″ dia.
128 „ 2	12	28	161 5 0	13 9 0	5 15 0	146 8 0	12 4 0	5 5 0	„
128 „ 3	20	50	241 3 0	12 1 0	4 16 0	216 18 0	10 17 0	4 7 0	„
128 „ 4	30	74	335 13 0	11 4 0	4 11 0	300 4 0	10 0 0	4 1 0	„
128 „ 5	40	100	430 2 0	10 15 0	4 6 0	383 10 0	9 12 0	3 17 0	„
128 „ 6	50	126	521 17 0	10 9 0	4 3 0	473 5 0	9 9 0	3 15 0	„
128 „ 7	6	14	103 8 0	17 5 0	7 8 0	95 11 0	15 19 0	6 17 0	5′ 0″ dia.
128 „ 8	12	30	167 17 0	14 0 0	5 12 0	152 13 0	12 14 0	5 2 0	„
128 „ 9	20	50	240 7 0	12 0 0	4 16 0	216 18 0	10 17 0	4 7 0	„
128 „ 10	30	74	337 0 0	11 5 0	4 11 0	302 11 0	10 1 0	4 2 0	„
128 „ 11	40	100	433 13 0	10 17 0	4 7 0	388 4 0	9 14 0	3 18 0	„
128 „ 12	50	126	530 6 0	10 12 0	4 4 0	473 17 0	9 10 0	3 15 0	„

128	,,	13	6	14	109 12 0	18 5 0	7 17 0	98 11 0	16 9 0	7 1 0	6′ 0″ dia.
	,,	14	12	32	180 15 0	15 1 0	5 13 0	158 8 0	13 4 0	4 19 0	,,
	,,	15	20	52	262 2 0	13 2 0	5 1 0	226 16 0	11 7 0	4 7 0	,,
	,,	16	30	74	353 12 0	11 16 0	4 16 0	303 15 0	10 3 0	4 2 0	,,
	,,	17	40	102	465 8 0	11 13 0	4 11 0	397 16 0	9 19 0	3 18 0	,,
	,,	18	50	128	567 2 0	11 7 0	4 9 0	483 6 0	9 13 0	3 16 0	,,
	,,	1a	6	14	82 12 0	13 15 0	5 18 0	74 8 0	12 8 0	5 6 0	4′ 6″ dia. (Welding omitted)
	,,	2a	12	28	124 2 0	10 7 0	4 9 0	109 1 0	9 2 0	3 18 0	, ,,
	,,	3a	20	50	181 3 0	9 1 0	3 12 0	156 13 0	7 17 0	3 3 0	,, ,,
	,,	4a	30	74	248 12 0	8 6 0	3 7 0	212 19 0	7 2 0	2 18 0	,, ,,
	,,	5a	40	100	316 1 0	7 18 0	3 3 0	269 4 0	6 15 0	2 14 0	,, ,,
	,,	6a	50	126	388 13 0	7 15 0	3 2 0	329 16 0	6 12 0	2 12 0	,, ,,
	,,	7a	6	14	82 0 0	13 13 0	5 17 0	73 18 0	12 6 0	5 6 0	5′ 0″ dia. ,,
	,,	8a	12	30	127 18 0	10 13 0	4 5 0	112 9 0	9 7 0	3 15 0	,, ,,
	,,	9a	20	50	179 10 0	9 0 0	3 12 0	155 16 0	7 16 0	3 2 0	,, ,,
	,,	10a	30	74	248 6 0	8 6 0	3 7 0	213 12 0	7 2 0	2 18 0	,, ,,
	,,	11a	40	100	317 2 0	7 19 0	3 3 0	271 8 0	6 16 0	2 14 0	,, ,,
	,,	12a	50	126	385 18 0	7 14 0	3 1 0	329 4 0	6 12 0	2 12 0	,, ,,
	,,	13a	6	14	86 10 0	14 8 0	6 4 0	75 3 0	12 11 0	5 7 0	6′ 0″ dia.
	,,	14a	12	32	138 1 0	11 10 0	4 6 0	115 8 0	9 12 0	3 12 0	,, ,,
	,,	15a	20	52	197 0 0	9 17 0	3 16 0	161 8 0	8 1 0	3 2 0	,, ,,
	,,	16a	30	74	263 6 0	8 16 0	3 11 0	213 3 0	7 2 0	2 18 0	,, ,,
	,,	17a	40	102	344 7 0	8 12 0	3 8 0	276 8 0	6 18 0	2 14 0	,, ,,
	,,	18a	50	128	418 0 0	8 7 0	3 5 0	333 18 0	6 14 0	2 12 0	,, ,,
	,,	1b	6	14	63 14 0	10 12 0	4 11 0	55 10 0	9 5 0	3 19 0	4′ 6″ dia. Lined 24 gauge corrugated iron.
	,,	2b	12	28	85 17 0	7 3 0	3 1 0	70 15 0	5 18 0	2 11 0	,, ,, ,, ,, ,,
	,,	3b	20	50	116 6 0	5 16 0	2 7 0	91 15 0	4 12 0	1 17 0	,, ,, ,, ,, ,,
	,,	4b	30	74	152 5 0	5 2 0	2 1 0	116 11 0	3 18 0	1 12 0	,, ,, ,, ,, ,,
	,,	5b	40	100	188 4 0	4 14 0	1 18 0	141 7 0	3 11 0	1 8 0	,, ,, ,, ,, ,,
	,,	6b	50	126	226 19 0	4 11 0	1 16 0	168 1 0	3 7 0	1 7 0	,, ,, ,, ,, ,,
	,,	7b	6	14	63 16 0	10 13 0	4 11 0	55 12 0	9 5 0	3 19 0	5′ 0″ dia. ,, ,, ,, ,,
	,,	8b	12	30	88 3 0	7 7 0	2 19 0	72 12 0	6 1 0	2 8 0	,, ,, ,, ,, ,,
	,,	9b	20	50	115 10 0	5 16 0	2 6 0	91 15 0	4 12 0	1 17 0	,, ,, ,, ,, ,,
	,,	10b	30	74	152 0 0	5 1 0	2 1 0	117 5 0	3 18 0	1 12 0	,, ,, ,, ,, ,,
	,,	11b	40	100	188 10 0	4 14 0	1 18 0	142 15 0	3 12 0	1 8 0	,, ,, ,, ,, ,,
	,,	12b	50	126	221 0 0	4 8 0	1 15 0	168 5 0	3 7 0	1 7 0	,, ,, ,, ,, ,,

Table CXV—*continued.*

	Fig. No.	Accommodation. Normal 3 hrs. A	Accommodation. Crush 1 hr. B	Cost—Complete. Total. £ s. d.	Cost—Complete. Per Capita. A £ s. d.	Cost—Complete. Per Capita. B £ s. d.	Cost—Materials Only. Total. £ s. d.	Cost—Materials Only. Per Capita. A £ s. d.	Cost—Materials Only. Per Capita. B £ s. d.	Remarks.
128	S.T.S. 13b	6	14	67 17 0	11 6 0	4 17 0	55 18 0	9 6 0	4 0 0	6′ 0″ dia. Lined 24 gauge corrugated iron.
	" 14b	12	32	96 10 0	8 1 0	3 0 0	73 5 0	6 2 0	2 6 0	" " " " "
	" 15b	20	52	129 5 0	6 9 0	2 10 0	93 3 0	4 13 0	1 16 0	" " " " "
	" 16b	30	74	166 3 0	5 11 0	2 5 0	115 8 0	3 17 0	1 11 0	" " " " "
	" 17b	40	102	211 4 0	5 6 0	2 1 0	142 14 0	3 11 0	1 8 0	" " " " "
	" 18b	50	128	252 3 0	5 1 0	1 19 0	167 9 0	3 7 0	1 6 0	" " " " "
	" 1c	6	14	59 12 0	9 12 0	4 5 0	51 8 0	8 11 0	3 13 0	4′ 6″ dia. No steel lining.
	" 2c	12	28	77 14 0	6 6 0	2 16 0	62 13 0	5 4 0	2 5 0	" " "
	" 3c	20	50	102 13 0	5 3 0	2 1 0	78 3 0	3 18 0	1 11 0	" " "
	" 4c	30	74	132 2 0	4 8 0	1 16 0	96 9 0	3 4 0	1 6 0	" " "
	" 5c	40	100	161 12 0	4 1 0	1 12 0	114 15 0	2 17 0	1 3 0	" " "
	" 6c	50	126	193 6 0	3 17 0	1 11 0	134 10 0	2 14 0	1 1 0	" " "
	" 7c	6	14	59 11 0	9 12 0	4 5 0	51 9 0	8 11 0	3 13 0	5′ 0″ dia. " "
	" 8c	12	30	79 4 0	6 12 0	2 13 0	63 15 0	5 6 0	2 3 0	" " "
	" 9c	20	50	101 5 0	5 1 0	2 1 0	7 11 0	3 18 0	1 11 0	" " "
	" 10c	30	74	130 14 0	4 7 0	1 15 0	96 0 0	3 4 0	1 6 0	" " "
	" 11c	40	100	160 3 0	4 0 0	1 12 0	114 9 0	2 17 0	1 3 0	" " "
	" 12c	50	126	190 12 0	3 16 0	1 10 0	132 18 0	2 13 0	1 1 0	" " "
	" 13c	6	14	62 17 0	10 10 0	4 10 0	51 10 0	8 12 0	3 13 0	6′ 0″ dia. " "
	" 14c	12	32	86 9 0	7 4 0	2 14 0	63 15 0	5 6 0	2 0 0	" " "
	" 15c	20	52	113 7 0	5 13 0	2 4 0	77 15 0	3 18 0	1 10 0	" " "
	" 16c	30	74	144 13 0	4 16 0	1 19 0	93 10 0	3 2 0	1 5 0	" " "
	" 17c	40	102	180 14 0	4 10 0	1 15 0	112 15 0	2 16 0	1 2 0	" " "
	" 18c	50	128	214 7 0	4 6 0	1 13 0	130 5 0	2 12 0	1 0 0	" " "
	159	16	24	100 0 0	6 5 0	4 3 0	—	—	—	
	161 A	1	2	4 7 0	4 7 0	2 4 0	2 6 0	2 6 0	1 3 0	Including concrete lining. Price per yard run.
	161 A	1	2	2 2 0	2 2 0	1 1 0	0 18 0	0 18 0	0 9 0	Excluding " " " "
	161 B	1	2	3 0 0	3 0 0	1 10 0	1 11 0	1 11 0	0 16 0	

163	B	1	2	1 18 0	1 18 0	0 19 0	0 19 0	0 19 0	0 10 0	Excluding ,, ,, ,, ,,
	B	1	2	4 19 0	4 19 0	2 10 0	2 12 0	2 12 0	1 6 0	Including ,, ,, ,, ,,
	C	1	2	1 16 0	1 16 0	0 18 0	0 18 0	0 18 0	0 9 0	Excluding ,, ,, ,, ,,
	C	1	2	4 9 0	4 9 0	2 5 0	2 13 0	2 13 0	1 7 0	Including ,, ,, ,, ,,
		1·5	3	4 17 0	3 5 0	1 12 0	2 19 0	1 19 0	1 0 0	Average price per yard run of trench and bunk recess.
184	B	2	5·6	12 2 0	6 1 0	2 3 0	11 19 0	6 0 0	2 3 0	Excluding gas and blast-proof doors, curtains and seating. Prices per yard run.
	C	2	5·6	12 11 0	6 6 0	2 5 0	10 7 0	5 4 0	1 17 0	do. do. do.
	D	2	5·6	14 1 0	7 0 0	2 10 0	11 12 0	5 16 0	2 1 0	do. do. do.
	E	2	5·6	11 11 0	5 16 0	2 1 0	10 0 0	5 0 0	1 16 0	do. do. do.
	F	2	5·6	8 10 0	4 5 0	1 10 0	8 0 0	4 0 0	1 9 0	do. do. do.
210	A	2	6	62 6 0	31 3 0	10 8 0	44 11 0	22 6 0	7 9 0	Price per yard run.
	B	2	6	79 8 0	39 14 0	13 5 0	56 18 0	28 9 0	9 10 0	,, ,, ,,
		55	100	1,745 17 0	31 15 0	17 9 0	909 0 0	16 11 0	9 2 0	Excluding decontamination equipment, etc.
		35	60	851 6 0	24 6 0	14 4 0	407 10 0	11 13 0	6 16 0	Excluding ventilation equipment.
222		7	28	159 19 0	22 11 0	5 14 0	115 18 0	16 11 0	4 3 0	Type A to resist ¼ cwt. bomb.
		7	28	211 19 0	30 6 0	7 11 0	155 12 0	22 5 0	5 11 0	,, A ,, ,, 1 ,, ,,
		7	28	524 11 0	74 19 0	18 15 0	355 16 0	50 17 0	12 14 0	,, A ,, ,, 2 ,, ,,
		7	28	709 17 0	101 8 0	25 6 0	505 19 0	72 6 0	18 1 0	,, A ,, ,, 6 ,, ,,
		7	28	2,122 4 0	303 3 0	75 16 0	1,514 16 0	216 8 0	54 2 0	,, A ,, ,, 1 ton ,,
		7	28	181 14 0	25 19 0	6 10 0	130 3 0	18 12 0	4 13 0	,, B ,, ,, ¼ cwt. ,,
		7	28	228 1 0	32 12 0	8 3 0	178 16 0	25 11 0	6 8 0	,, B ,, ,, 1 ,, ,,
		7	28	461 14 0	65 19 0	16 10 0	364 16 0	52 2 0	13 1 0	,, B ,, ,, 2 ,, ,,
		7	28	809 7 0	115 12 0	28 18 0	592 6 0	34 12 0	21 3 0	,, B ,, ,, 6 ,, ,,
		7	28	2,221 17 0	317 8 0	79 7 0	1,595 5 0	227 18 0	57 0 0	,, B ,, ,, 1 ton ,,
		7	28	144 12 0	20 13 0	5 3 0	101 19 0	14 11 0	3 13 0	,, C ,, ,, ¼ cwt. ,,
		7	28	227 11 0	32 10 0	8 3 0	164 16 0	23 11 0	5 17 0	,, C ,, ,, 1 ,, ,,
		7	28	424 18 0	60 13 0	15 4 0	299 15 0	42 16 0	10 14 0	,, C ,, ,, 2 ,, ,,
		7	28	798 16 0	114 2 0	28 10 0	553 2 0	79 0 0	19 15 0	,, C ,, ,, 6 ,, ,,
		7	28	1,512 17 0	216 2 0	54 1 0	1,004 12 0	143 10 0	36 0 0	,, C ,, ,, 1 ton ,,
		7	28	97 17 0	13 19 0	3 10 0	53 0 0	7 11 0	1 18 0	,, D ,, ,, ¼ cwt. ,,
		7	28	183 0 0	26 3 0	6 11 0	99 19 0	14 6 0	3 11 0	,, D ,, ,, 1 ,, ,,
		7	28	287 6 0	41 1 0	10 5 0	167 10 0	23 19 0	5 19 0	,, D ,, ,, 2 ,, ,,
		7	28	419 6 0	59 18 0	15 0 0	246 8 0	35 4 0	8 16 0	,, D ,, ,, 6 ,, ,,
		7	28	687 16 0	98 5 0	24 11 0	415 10 0	59 7 0	14 18 0	,, D ,, ,, 1 ton ,,

works finished completely by contract, and also for materials alone—assuming the work is carried out by volunteer labour.

The reader will no doubt be struck with the diversity of the results but reference to the illustrations, referred to by figure number in the table, will show that they cover a wide range of constructions and give various degrees of protection.

The summarised figures given in Table CXVI will be found of use in approximate estimates for large scale works.

TABLE CXVI

APPROXIMATE PER CAPITA COSTS AT "NORMAL" CAPACITIES

	Complete.	Materials only
	£	£
*Fire protection	2	1
†Gas protection	1	0·5
Gas and fire	3	1·5
Splinter protection	4	2
Gas, fire and splinter protection . .	5	3
Light bomb, fire and gas . . .	4–20	2–11
Medium bomb, ,, ,, . . .	15–30	9–18
Heavy bomb, ,, ,, . . .	40–60	24–36

* Includes fire protection of shelter only—not fireproof clothing or the protection of property.

† Includes gas-proofing of shelter only—not masks or clothing.

The range of costs given in each case covers variations in the design of shelter and it will be seen that the cost of providing materials only for the most meagre protection to the complete cost of full protection against heavy bombs covers a 120-fold increase from 10*s*. to £60 *per capita*.

To provide full bomb-proof protection to the forty-five million urban population in this country would involve an expenditure approaching 2,700 millions sterling and it would require the imagination of an H. G. Wells to visualise a fully protected city.

Finance

On p. 157 will be seen a table showing the probable daytime distribution of the whole urban population of the country both

before and after evacuation. It would therefore appear that allowing for a certain necessary amount of duplication of shelter accommodation, provision should be made ultimately for the following protection :—

TABLE CXVII

	Population.	Cost per capita.	Total cost.
Principal danger zones requiring shelters proof against *heavy bombs* . . . . . . (Allowing for 33⅓ per cent. additional accommodation for use before evacuation.)	4,000,000	£30	£120,000,000
Medium danger zones requiring shelters proof against *small bombs*	20,000,000	£10	£200,000,000
Outskirts of towns requiring *splinter-proof protection*	8,000,000	£5	£40,000,000
(Allowing 14 per cent. additional accommodation.)			
Rural districts requiring *no special protection*	15,000,000	—	—
TOTAL POPULATION FOR WHICH SHELTER ACCOMMODATION IS NEEDED .	32,000,000		£360,000,000

It is probable that a fair percentage of shelters, especially of the light bomb and splinter-proof type, can be provided by the adaptation of existing premises, thus reducing materially the total cost of new work. Against this saving has to be set the costs of transportation, temporary housing and general provisioning of the evacuated population.

On the whole, therefore, a total national expenditure approximating 300 millions sterling will be incurred in the adequate passive defence of the civil population of the British Isles.

That this expenditure shall be as productive as possible it will be necessary to ensure that the highest possible proportion of shelters are constructed for the dual purpose of some peace-time use and the assurance of protection in emergency.

Public money will be expended as well as a great deal of private money, but the very nature of the construction will render shelters less vulnerable than ordinary buildings in air

raids, and investment in them ought therefore to be "*safer* than Bricks and Mortar."

Banks, building societies, insurance companies and other investing corporations ought in the national interests to facilitate the loan of capital for protective works and buildings provided with shelter accommodation, which ought to carry an appropriately increased valuation.

Well-thought-out and soundly constructed shelters should command high valuations for mortgage purposes, but valuers dealing with structural A.R.P. schemes will need to keep the accepted principles of protection well in mind.

The estimated expenditure of 300 millions would be spread over the construction period, which the author would estimate as four years for the completed national scheme. This represents an annual charge of £1 10*s*. per head of population of the whole of the British Isles per annum for the "Four Year Plan"—only 25 per cent. of the peace-time annual *per capita* expenditure on the armed forces.

The War Risk—Insurance

The steady growth of insurance business generally evidences the fact that the public are coming more and more to realise that insurance is the best individual contribution to the lessening of the risks and uncertainties of modern civilisation.

Insurance companies have never intended to cover war risks and to make the position quite clear to policy holders have sent out a notice to the effect that the exclusion of the risks of war has been agreed to by the Insurance Companies generally, who have come to the conclusion that these risks are not proper subjects for insurance.

It had been suggested by property owners that the risk might be covered

(*a*) by some sort of insurance ;
(*b*) by a mutual pooling scheme ; and
(*c*) by a Government scheme.

(*a*) In any kind of insurance the first problem is to calculate a premium and the first difficulty that presents itself is the impossibility of estimating with any degree of accuracy the probable damage to property in this country in the event of war.

Again it is not possible to foretell how soon hostilities would commence.

Thus no safe foundation exists upon which actuarial calculation can be based and to make a guess at the premium would be nothing short of gambling. Even if a premium were set at a prohibitively high figure the reserves accumulated would not be sufficient to cover the risk adequately were war to break out within a few years of the inception of the scheme.

It would therefore appear that insurance against war risks at the present time is an impossibility.

(*b*) Some sort of insurance against or compensation for damage done in war can be effected by means of a mutual pooling scheme and a company has been formed with this object in view.

Even if the country enjoys many years of freedom from damage by war it would appear that unless this scheme were operated on a nation-wide basis, early losses of unknown magnitude might easily wipe out all reserves.

(*c*) As to insurance by the Government, the President of the Board of Trade stated on May 4th, 1937, that after a careful review of all the circumstances the Government had reached the conclusion that no scheme of insurance of property in this country against war risks on land would be appropriate to the conditions of a future war so far as they could be foreseen.

The National Federation of Owner-Occupiers and Owner Residents Associations have however put forward proposals which would seem to merit serious consideration :—

(1) They would welcome a scheme of compulsory insurance from the point of view that everyone in the country would contribute to the common insurance pool.

(2) Any scheme decided upon should not involve the Government in setting up a new Department, as the cost of administering the scheme should be borne by the policyholders.

(3) The Government should grant a special Charter to one Mutual Insurance Corporation on terms which would prevent it making profits, and its administrators should be men working for honour and the good of their fellows. The staff would, of course, be paid. The premiums could be collected through existing insurers.

(4) All monies of the Chartered Corporation would be

invested only in Government Securities. Solvency would be thereby ensured during times of peace, and the fund available to the Government would have many benefits which a Chancellor of the Exchequer would appreciate.

(5) Should war occur and the funds of the Chartered Corporation prove insufficient to meet claims, the Government guarantee would enable it to borrow to any amount to meet claims, and as premiums would still continue, repayment of loans would be assured. The Government, presumably, would have to find the money for compensation if there were no insurance, and it is therefore reasonable to state that by the scheme of insurance the Government's position would be bettered.

Air Raid Shelters—Rates and Taxation

Under the present state of the law valuation officers are obliged to bring to the notice of local assessment committees any improvement in value of property brought about by the construction of air raid shelters, and as a result public-spirited landlords and owner-occupiers who engage in the provision of shelters at the urgent behest of the Home Office are likely to be penalised through increased assessments to Income Tax under Schedule A and in increased rates.

It cannot be thought that this is the serious intention of the Government and as the Ministry of Health has no power at present to interfere, appeal should be made to the local assessment committee.

It is true that Sir John Simon, Chancellor of the Exchequer, said in the House of Commons on May 26th, 1938, that he would not tax "improvements, additions, or alterations" made to a house or factory to provide air raid shelters.

No increased assessment under Schedule A will be made where these domestic precautions are taken. Where a shelter is built specially by public authorities it will not be assessed for income tax. A special Act of Parliament will order rating authorities to give equal exemption from their assessments.

But in the language of the statutes such "alterations, additions, or improvements" will escape increased tax and rates only if they are provided "solely for the purpose of protection in the event of air raids."

A peace-time utilisation of an air-raid shelter might therefore render the " addition or improvement " liable to taxation.

EVACUATION

Evacuation necessarily forms an important part of and general scheme for passive defence and the French plans are worthy of consideration.

In 1936 the French Government issued a handbook on evacuation, and the following extracts and notes are of interest.

There is no doubt that the orderly and methodical execution, at the time of need, of a plan of evacuation which has been carefully prepared in every detail during peace time is calculated to save a great number of human lives. Such a result makes it worth while to make every effort to prepare such a plan, in spite of all difficulties that may be encountered. The general scheme proposed by the French handbook recommends :—

" (1) All persons who will leave the town voluntarily should be encouraged to do so.

" (2) Permanent evacuation of the people unimportant from the military or administrative point of view into the country districts.

" (3) Evacuation of people whose relatives must remain in the town, to places nearby.

" (4) Nightly evacuation of people who must work in the town.

" (5) Shelters to be provided for all people who must remain in the town.

" These plans must be formulated by the mayor of the town, and he must arrange with the local authorities of the villages how many refugees each village can accommodate. The order for evacuation will be given by the Government before they issue the order for the mobilisation of the armed forces,

" It is proposed that each person should have an evacuation ticket at the outbreak of a war and these tickets are already printed.

" Such a ticket would read as follows :—

" ' Mr. X. is instructed to take the 8 p.m. train this evening from the Gare du Nord for Amiens. He is to take

with him his wife and four children, travelling in seats Nos. 37–42 inclusive.' "

In this country detailed arrangements are now made and Sir Samuel Hoare, in the House of Commons on June 1st, 1938, explained that time-tables had been worked out to move 3,500,000 people by rail fifty miles from London in seventy-two hours, without train tickets. Normally, people will not abandon their homes except from proved necessity, and in Barcelona, during the bombing, the population was said to have increased by over 20 per cent., due to the influx of refugees seeking food supplies. Hunger appears to have been regarded a greater peril than that from the air. Evacuation is obviously a more effective passive measure than the provision of shelter accommodation but complete evacuation is not possible.

It would probably be safe to assume that all children under the school-leaving age, babies and their mothers, old people and invalids, amounting to about 25 per cent. of the urban population, could be permanently evacuated to areas requiring no special protective measures.

All specially dangerous locations might also be vacated except for a permanent cadre of key men, thus possibly accounting for another 10 per cent. of the population.

The central zones of cities and areas near military objectives would need the highest degree of protection and the outskirts splinter-proof protection.

The difficulties attendant upon evacuation would cause

Table CXVIII

Approximate Day-time Distribution of Urban Population

	Before evacuation.	After evacuation.
Principal danger zones	13,000,000	3,000,000
Medium danger zones	22,000,000	20,000,000
Outskirts of towns	10,000,000	7,000,000
Rural districts	Nil	15,000,000
Totals	45,000,000	45,000,000

delays in its execution and it would therefore be necessary to provide shelter protection on a crush capacity basis for larger numbers at the outset.

It would consequently appear that the distribution of the urban population would be adjusted in an emergency somewhat on the lines indicated on p. 662:—

At night times a large proportion of the population in the principal and medium danger zones would move to the suburbs, thus necessitating the provision of duplicate shelter accommodation for it.

OUTLINE OF THE BRITISH GOVERNMENT'S EVACUATION SCHEME

H.M. Government has made a scheme for the removal of children and certain adults from congested areas should the country be threatened with war. The County of London and the neighbouring Boroughs of Acton, Barking, East Ham, Edmonton, Hornsey, Ilford, Leyton, Tottenham, Walthamstow, West Ham and Willesden are the areas to which the undernoted arrangements apply.

The London County Council and the Councils of the Boroughs mentioned above are making the arrangements in London on behalf of H.M. Government, and the Government is taking responsibility for all matters of policy and for the arrangements in the Areas to which children and others will be sent.

The plan depends for its success on the help which all citizens can give.

For whom are the Arrangements being made ?

(1) For school children whose parents wish them to go. This applies to all school children, whatever kind of school they attend. No children will be taken without their parents' consent. That consent will be held to be given if parents send their children to school on a day announced for evacuation. If parents do not wish their children to leave London they must keep them at home on that day.

(2) For children below the age of five whose parents wish them to go, if accompanied by their mothers or some other

suitable persons chosen by the parents, or if attached to a day nursery or nursery school.

(3) For women expecting to be confined and who wish to go.

(4) For blind persons who wish to go.

No person who is not in the classes mentioned above is included in the scheme. It may be necessary to take serious note of any attempt by an unauthorised person to join a party.

What will there be to pay ?

Nothing will be charged for transport.

School children who go with their teachers will be provided with board and lodging and the Government will pay the people in the country who accommodate the children. A contribution towards the cost may later on be required from the responsible person, for example, the father of the children, if he can afford to pay.

Lodging only will be provided for adults and children under five who accompany them. Adults will be expected to pay for food for themselves and the children with them. A contribution towards the cost of the lodging may later on be required from those responsible, if they can afford it.

If people find themselves without means in the Reception Areas, assistance will be given by the Government.

What Conditions are there ?

(1) Should it be necessary to put these plans into force, announcements will be made by radio and the press. Those who are leaving London will have to go to Assembly Points at times which will be announced. They will be organised into parties. A person or child must go with the party to which he will be attached and no other. All must go in an orderly fashion and must obey the directions of the leaders of the parties and the railway officials.

(2) Only those will be taken *who register themselves* in the way described in the following paragraphs.

Assembly Points

The Assembly Points for school children will be the schools they attend, unless parents decide to send them to other schools as explained below.

The Assembly Points for children under five with their mothers or other responsible persons will be the schools where the mothers register, and should be the nearest elementary school to the parents' home.

Blind people, and women expecting to be confined, will be informed later on of their Assembly Points.

Registration

School children will go with their schools accompanied by their teachers, if the parents wish it. This applies to every kind of school. In the crisis of September, 1938, many parents informed the school teachers that they wished their children to go. If this is still the parents' wish, nothing more need be done. Parents who have not yet told the teachers their wishes should do so at once.

If the children of a family go to more than one school, and the parents wish their children to be together, the parents can choose with which school all their children should go. Parents must at once tell the heads of each of the schools what their wishes are if they have not already done so.

Children under five years of age and their mothers. Mothers wishing to go and take children under five *must register, or must register the names of suitable persons* who will be responsible for the children.

Some children under five attend school. Mothers may choose whether they will take these children themselves, or whether they will let them go with the school, *but they must register in any case.* A mother cannot go herself without a child under five.

Mothers who wish to go themselves with children under five and who have older children at school may choose whether to take the older children with them or to let the older children go with their schools, *but the mothers must register in any case.* They should inform the head teachers of the schools of their wishes.

There can be no guarantee that the parties of mothers and children with them will reach the same destinations as the school parties. Children who go with their schools will be provided with board and lodging ; children with their mothers or other suitable persons with lodging only.

How to Register

For the registration of mothers of children under five (or other suitable persons chosen by parents) all elementary schools will be open from 5 30 p.m. to 9 p.m.

Children should not be taken to the registration places, and will not be admitted.

Women expecting to be confined who wish to go can register themselves at any maternity and child welfare centre at any time it is open. Addresses of the centres can be obtained at any Town Hall or Post Office.

Blind people who wish to go can register themselves through their home visitor at the appropriate district office at any time.

Inquiries

If a blind person does not know the address of the District Office, someone should write on his behalf to the Education Officer, The County Hall, S.E.1.

Inquiries about the scheme (except those on behalf of blind people) cannot be answered by post or telephone but they will be answered at any elementary school.

Helpers Wanted

Many thousands of voluntary helpers are needed in putting into force the scheme outlined in the foregoing paragraphs,

(1) To accompany parties from assembly points to entraining stations; or

(2) To do the foregoing and to accompany parties into the Reception Area and stay there, either for a few days or for an indefinite period at the choice of the volunteer; or

(3) To lend and drive cars.

The essential qualities in a helper accompanying a party are common-sense, kindliness, and a cool head in an emergency.

For escorting certain of the parties, women will be particularly suitable.

CHAPTER XVII

ORGANISATION OF A.R.P.

In a paper read at a general meeting of the Air Raid Protection Institute on June 13th, 1939, Colonel G. M. Routh, C.B.E., D.S.O., F.A.R.P.I., gave much detail on the organisation and control of A.R.P. Services in Europe :—

" Government by the people for the people " said he, " must always suffer in its potentialities for executive control as compared with a totalitarian regime, since every important decision must be based on the slowly formed opinions of a large number of persons concerned, instead of immediate action on the personal order of a dictator. As a set-off against this democratic leeway, we should look for some far-reaching corrective to compensate these weaknesses in the organisation of its chosen executive. It is the object of this paper to examine the channels of control in the passive defence of this country as compared with what is considered necessary across the water.

" Germany and France, each in their own way, have taken A.R.P. seriously. Germany spent several hundred millions sterling in deciding, with typical Teutonic thoroughness, on what was neeeded to ensure that the danger from the air would neither cripple the Fatherland nor weaken her diplomatic counsels. Their Air Raid League (*Luftschutzbund*) has 13 million members, about seven times the total number of British volunteers, and simple control by the Air Ministry, with unquestioned authority to make any person carry out any A.R.P. measure, has ensured that no enemy can now effect decisive results, either psychologically or physically, when dealing with the civil population.

" The A.R.P. Department in Germany is thus controlled by the Ministry which deals also with Active Defence, both on the ground and in the air. This has certain advantages."

Fig. 295 shows diagrammatically the organisation of A.R.P. control in Germany in 1939—an organisation which functions without change in both peace and war.

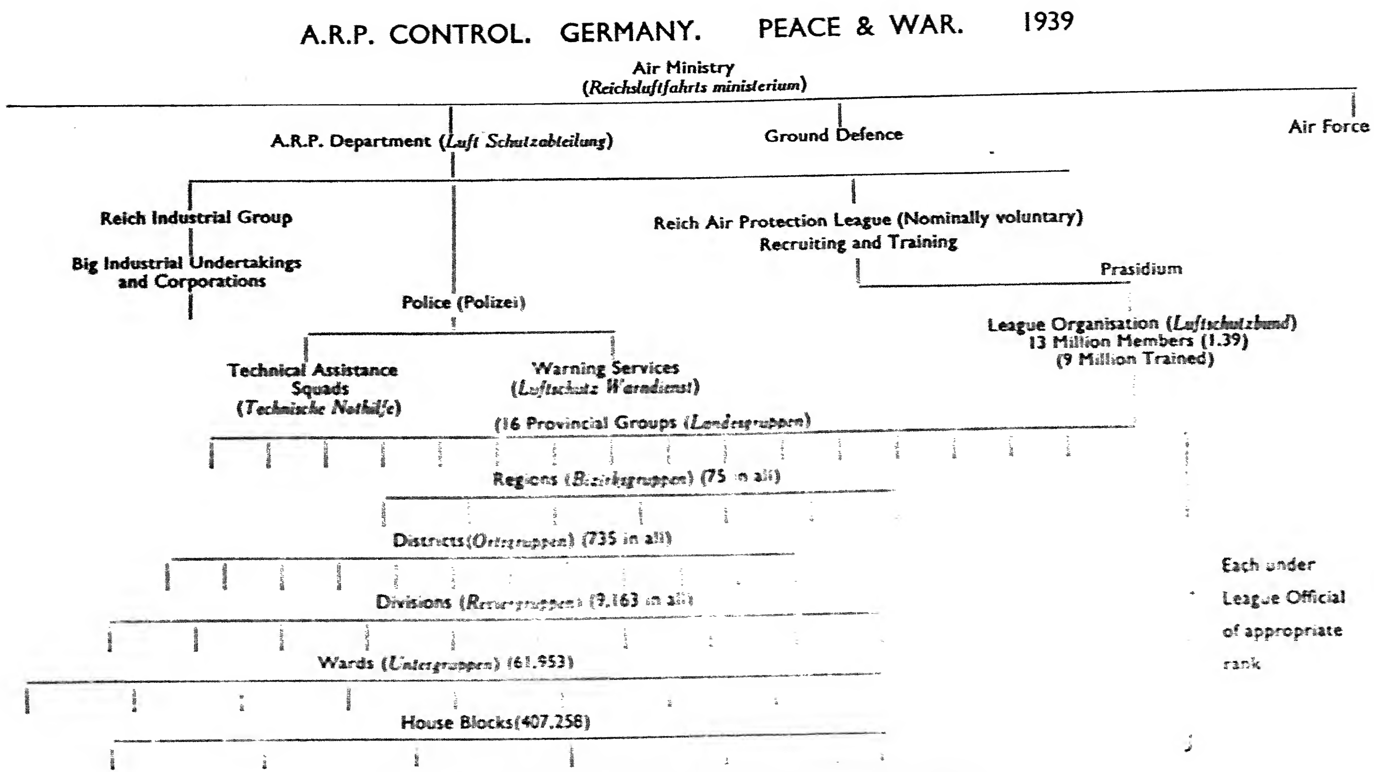


FIG. 295.—German organisation of A.R.P. in peace and war.

(Courtesy Col. Routh & A.R.P. Inst.)

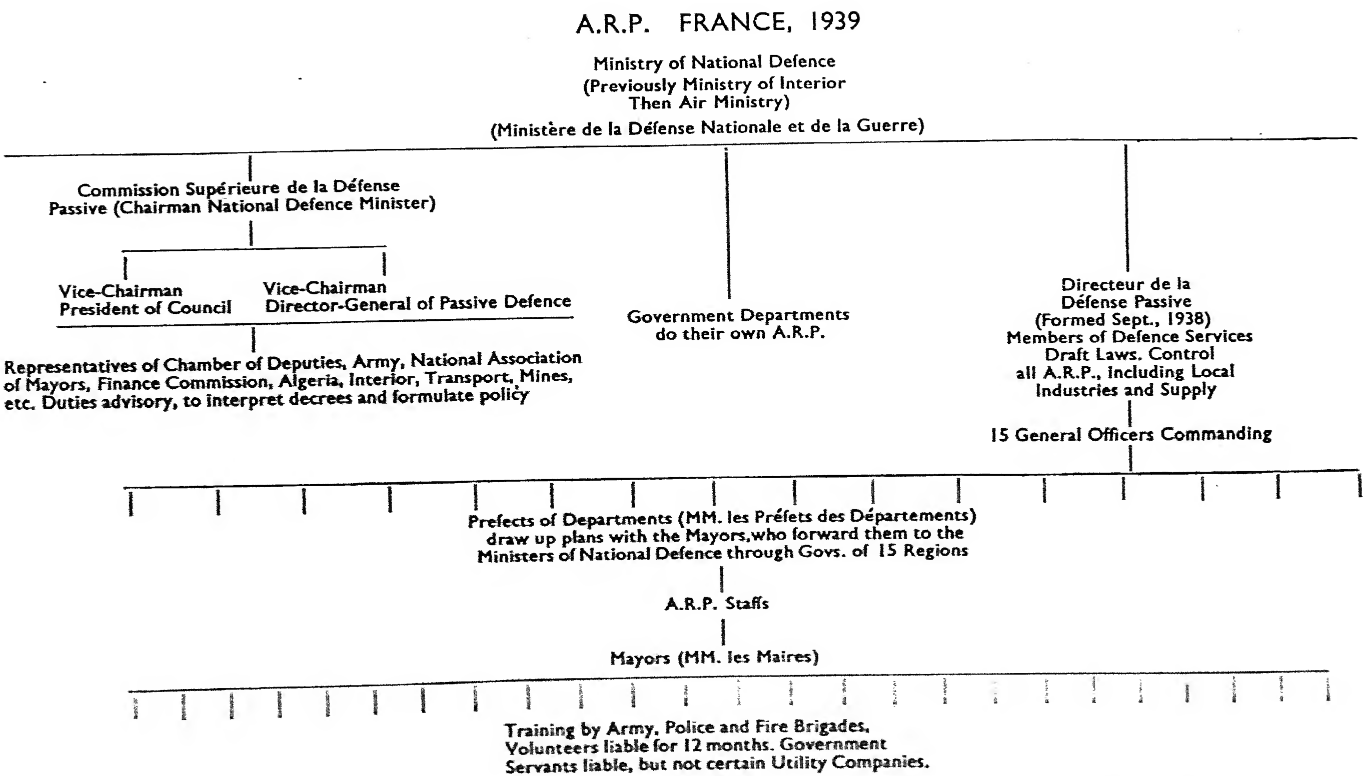


FIG. 296.—French A.R.P. organisation.

(Courtesy Col. Routh & A.R.P. Inst.)

Colonel Routh goes on to say :—

"France aims at the same results as Germany, but expresses them differently. Where Germany envisages only temporary hostile air superiority on the home front, the French contemplate more sustained hostile effort, and attempt to provide for more continuous protective measures than across the Rhine.

"Passive defence in France is under the direct control of the Ministry of National Defence, which exercises its functions in two ways. The 'Direction de la Défense Passive,' consisting of members of the Defence Services, drafts laws and controls all A.R.P. in the country (except in Government Departments, who are responsible for their own passive defence). These powers are exercised through the general officers of the fifteen military regions, who are entirely responsible both in peace and war. The Prefects of these departments draw up plans with the mayors in their areas, which are forwarded by the generals to the Ministry of National Defence for approval. The mayors are responsible in their own areas, with the assistance, for training purposes, of the Army, police, and fire brigades. 'Volunteers' are liable for twelve months, but in practice nearly everyone except key personnel in essential services is called on to do his bit."

Fig. 296 shows the organisation in France and Figs. 297 and 298 the A.R.P. organisation in Great Britain in peace and in war respectively.

In the organisation of Air Raid Precautions under the Air Raid Precautions Act the Home Office is responsible for co-ordinating and organising all passive measures for the defence of the civil population. Notwithstanding the fact that considerable executive powers are vested in local authorities and decentralisation is carried out as far as possible, all schemes involving expenditure of public monies require the approval of the central authority. The Home Office have issued Air Raid Precautions handbooks and have published memoranda and Home Office circulars on most aspects of the subject and the reader is referred to these for more detailed information. A complete list is given in Appendix IV.

The whole of the Air Raid Precautions service is voluntary, much of it is part time but some members are required for whole time duties in war, and these are paid.

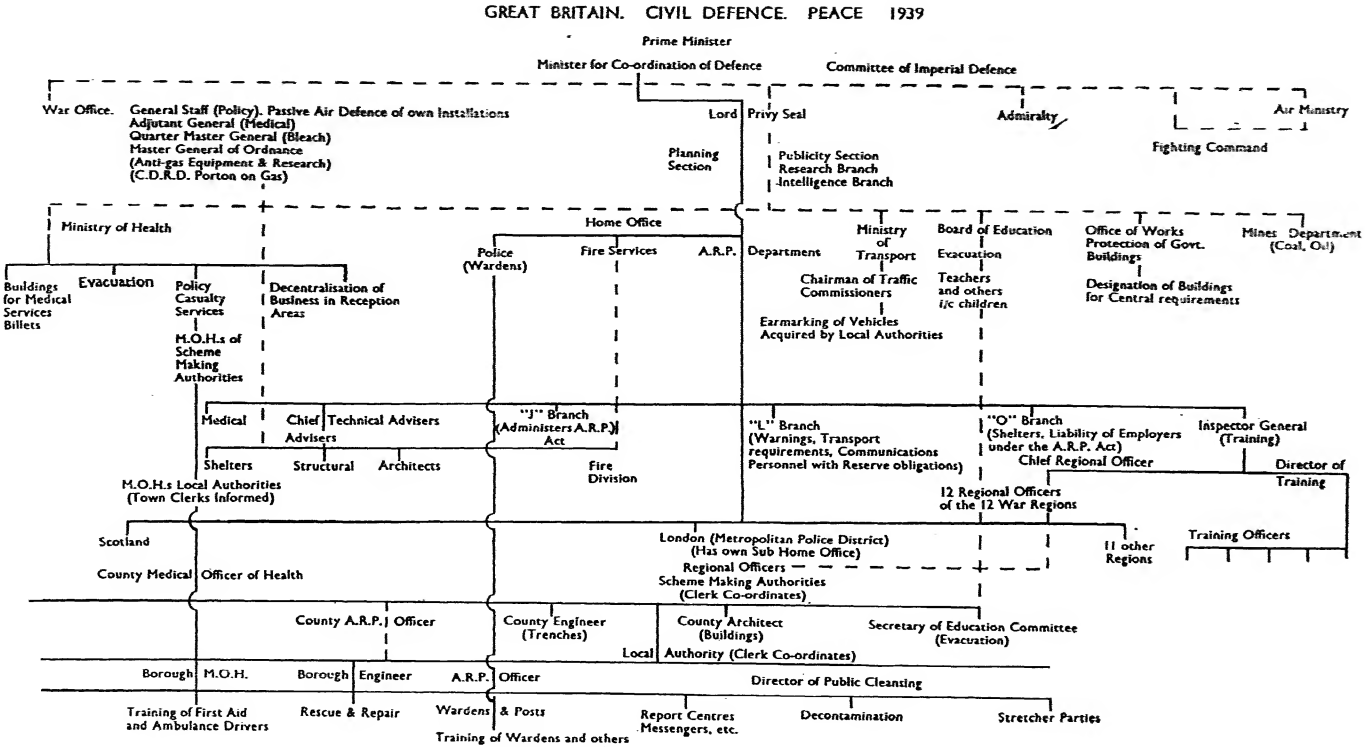


FIG. 297.—Organisation of Civil Defence in Britain in peace time.

(*Courtesy Col. Routh & A.R.P Inst.*).

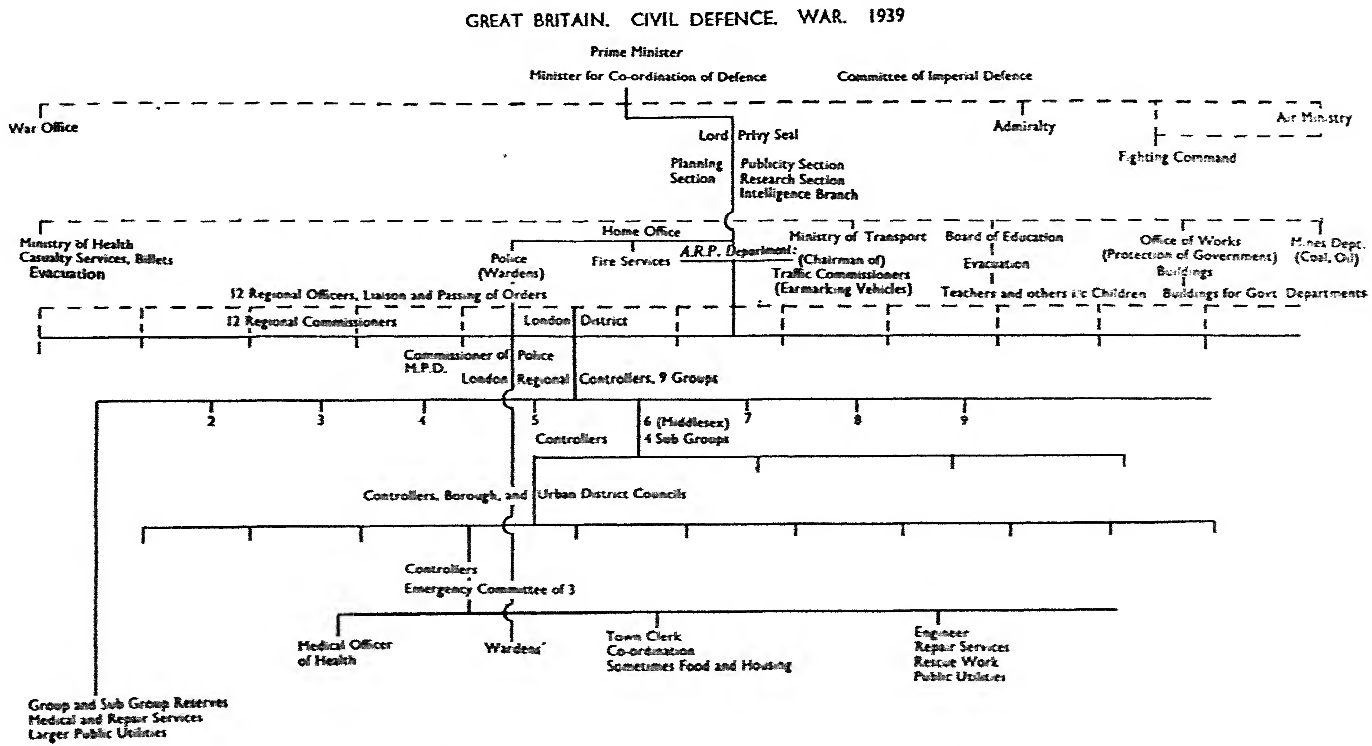


FIG. 298.—Organisation of Civil Defence in Britain in war.

(Courtesy Col. Routh & A.R.P. Inst.)

Apart from the fact that casualties in the service should be expected at the time of an emergency a number of the trained *personnel* may not be available for one cause or another and the numbers trained should therefore be greatly in excess of the numbers required for the service as outlined. A general perspective of the organisation may be gauged from the tables which follow, and the attention of the reader is drawn to the references given at the foot of each for any further detailed information required.

AIR RAID PRECAUTIONS

Actions to be taken

(A) By Government

In Peace time

General organisation of national A.R.P. scheme.
Advice to local authorities, employers and householders on structural A.R.P. organisation and individual conduct.
Accumulation of stocks of materials and equipment.
Examination and testing of equipment.
Training instructors.
Research.

In an Emergency

Issue of warnings.
Control of defensive operations.
Issue of emergency decontamination materials and defensive equipment.
Control of evacuation and of maintenance of urban populations, carried out by local authorities and Board of Education.
Police services.
Fire services.

(B) By Local Authorities

In Peace time

Preparation of A.R.P. schemes for—
First aid and hospital treatment.
Rescue.
Decontamination.
Demolition.
Repair.

In an Emergency

Control of—
Wardens,
First aid.
Rescue.
Decontamination.
Auxiliary services.
Fire precautions.
Dissemination of warnings.

In Peace time	*In an Emergency*
Augmentation of police.	Lighting restrictions.
Fire, and	Essential services.
A.R.P. *personnel*.	Gas detection.
Recruitment and training.	Emergency communications.
Evacuation.	Provision of emergency shelters.
Lighting control.	
Protection of public buildings.	
Provision of public shelters.	

(C) By Statutory Undertakings

In Peace time	*In an Emergency*
Preparation of emergency schemes and installation of stand-by equipment and organisation of alternative services.	Close co-operation with G.P.O. and local authorities in maintenance of essential services.

(D) By Employers

In Peace time	*In an Emergency*
Preparation of schemes for protection of premises and *personnel*.	Keep industry and commerce functioning as far as is compatible with safety of employees.
Organisation and training of fire squads and first aid services.	Engage staff, unoccupied in the emergency, in organised A.R.P. service.
Encourage employees to join A.R.P. services.	

(E) By Householders and Members of the Public

In Peace time	*In an Emergency*
Learn means of protection and self-help.	Join A.R.P. service.
Prepare premises for passive defence.	Put into effect all emergency measures, then "carry on" and help your neighbour.

TABLE CXIX

AIR RAID PRECAUTIONS SERVICES

WARDENS

Home Office

Local Authorities

Controlling Official: Chief Constable

Executive Head: Chief Warden

Divisional Warden (80,000 population) — as necessary

Head Warden (8,000 population) — 9 other groups

Senior Warden (500 population) — 15 other posts

Warden (100 population) — 4 other Wardens

Wardens should be men over forty-one—or women.

Duties.

Distribution, fitting and maintenance of gas masks.
Reports of bomb damage and presence of gas.
Shepherding public to shelters.
Lighting restrictions.
General liaison between all A.R.P. services, police, fire brigade and public.

Refs. 4 and 12 (see Appendix IV.).

TABLE CXX

AIR RAID PRECAUTIONS SERVICES

FIRST AID

Home Office

|

Local Authorities

|

Controlling Officer: Medical Officer of Health

|

Executive Head: First Aid Commandant

|

First Aid Post

		Men t.	Men u.	Women t.	Women u.
Population	3,000–20,000 small	20	26	20	14
,,	20,000–30,000 medium	26	20	26	18
,,	30,000–60,000 large	32	24	32	22

(allows two shifts)

|

Ambulance Transport Officer

|

Ambulance Services

|

2 ambulances per First Aid Party
Each ambulance with 1 woman driver
and 2 women attendants

First Aid Party

|

4 men (over 30)
1 car to each party.

14 parties per 100,000 population. Executive Head. First Aid Commandant.

+ 25 per cent. reserve required in towns.

NOTE at First-Aid Posts casualties are divided into
(*a*) Wounded.
(*b*) Contaminated unwounded.
t. Trained. *u*. Untrained.

Refs. 9, 28 and 68.

Table CXXI

AIR RAID PRECAUTIONS SERVICES

Rescue

Home Office

Local Authorities

Controlling Officer : County or Borough Engineer

Executive Head : Superintendent of rescue parties

Foreman	6 parties per 100,000 of the population.

Foreman

6 or 8 men (over 30)
according to the equipment.
(Trained Contractors' Men or Works Dept. Employees.)

Duties

Extrication of casualties from damaged buildings.

Demolition of dangerous buildings, (interchangeable with decontamination squads.)

Note.—Unexploded bombs are disposed of by the appropriate corps of the local fighting services, Officers commanding which should be notified by Wardens through the police.

Refs. 10 and 68.

TABLE CXXII

AIR RAID PRECAUTIONS SERVICES

DECONTAMINATION

Home Office

Local Authorities

Controlling Officer: County or Borough Engineer

Executive Head: Chief of Decontamination Squads

Squad of 6 men | 6 squads per 100,000 population

(Street Cleansing Staff or County Highway Employees.)

Duties

Arduous and exacting

Decontamination of streets, buildings, vehicles, barges, utensils, tools and materials.

Should be trained to assist in rescue, demolition or repair.

Based on depots.

References 1, 4, 11 and 68.

TABLE CXXIII

AIR RAID PRECAUTIONS SERVICES

ANCILLARY

Home Office

|

Local Authorities

|

Ancillary Services

Report Centre Men over 45— and Women. | Messengers— Motor cycle, pedal cycle, or on foot. Youths 16–18.	Storemen, Clerks, etc. Men over 30 years.	Reserves

Ref. 68.

TABLE CXXIV

AIR RAID PRECAUTIONS SERVICES

FIRE PRECAUTIONS

Home Office

|

Local Authorities

|

Controlling Officer : Chief Officer of the Fire Brigade

|

Established Brigades

|

Auxiliary Fire Service (A.F.S.)

|

Twice the number of men needed should be trained
Personnel : according to local requirements
Men 25–50
Women for watch-room and clerical duties

|

In emergency auxiliary *personnel* would be attached to Fire Brigade Station or auxiliary fire station.

References 12, 31, 33, 34 and 68.

A.F.S. *personnel* receive training by established brigades as below:

Sixty hours for fire-fighters and thirty hours for others.

Owner-drivers of cars and motor boats required for trailer engines and fire floats.

Water from canals and rivers to be pumped to supplement water hydrant services.

Business firms urged to form and equip fire brigades, the training of which would be undertaken by the established Brigades.

Much may depend upon the efficiency of the A.F.S.

TABLE CXXV

AIR RAID PRECAUTIONS SERVICES

POLICE

Home Office

|

Police Forces

|

First Police Reserve
(full time and paid)

|

Special Police Reserve
(full time and paid)

|

Special Constables
(part time and unpaid)

|

The Observer Corps—Branch of
the Special Constabulary

Duties

Too well known to need enumeration.

Ref. 15 and 68.

Table CXXVI

AIR RAID PRECAUTIONS SERVICES

Warnings

Home Office

Local Authorities

Public Warnings
(whistles or sirens)

Local warnings by Wardens

(Whistles, rattles or bells)

Refs. 15 and 82.

Table CXXVII

AIR RAID PRECAUTIONS SERVICES

Lighting Restrictions

Home Office

Police	Local Authorities	Statutory Companies
Air Raid Wardens	Street Lighting	Railways, etc.
Public		

Refs. 15 and 37.

TABLE CXXVIII

AIR RAID PRECAUTIONS SERVICES

ESSENTIAL SERVICES

Home Office

|

Co-ordination by Local Authority and G.P.O.

|

Statutory utility undertakings

|

Auxiliary maintenance services

TABLE CXXIX

AIR RAID PRECAUTIONS SERVICES

GAS DETECTION

Home Office

|

Local Authorities

|

Head Wardens

|

Gas Detection Officers

Ref. 24.

LIGHTING RESTRICTIONS

In the future air raid warning restrictions on lighting are likely to be more drastic than those enforced in the Great War.

The whole country is likely to be plunged into darkness for the purpose of depriving enemy airmen of an easy means of checking their position.

Normally, any village or town is conspicuous from the air at first as a general glow and later a closer view shows streets and general centres of nocturnal activity.

The map of the locality is clearly revealed by unscreened illumination and even the glow from gas or electric fires is one which cannot be allowed to contribute to the general level of illumination.

The immediate plunging of the locality into darkness by the switching off of electric power from the generating stations would also interfere with the running of trains, trolley buses, lifts, drainage pumps, and electrically-driven machinery of all kinds and this, therefore, cannot be contemplated.

Apart from this the vital necessity of maintaining illumination in essential control stations, operating hospitals, etc., has brought about the installation of emergency lighting systems which automatically light up on the cessation of the current from the main supply.

In time of war, all windows, skylights and glazed doors would have to be rendered opaque at night and this can best be achieved by the fitting of dark blinds. These must be installed so as to produce complete invisibility from outside and *all* rooms in a building likely to be occupied after dark should be fitted with them.

Suitable material may run short when the need arises, and all owners and occupiers of premises are therefore urged to obtain and install the necessary blinds and fittings now.

The "black-out" is one of the first expedients of passive defence to be adopted, but to be effective it must be absolutely complete.

We have not yet progressed as far in illumination by night as we had in the War by way of the firing of dummy flashes from the false battery positions to confuse enemy observers, and sound "locating" devices. We do not yet contemplate the

"alteration of the map" by the temporary removal of city lights to rural districts but we *can* extinguish or shield all city lights from aerial observation.

Strong blinds behind windows and under skylights also serve to minimise danger from glass shattered by the explosion of bombs.

For emergency use black and green obscuring paints are now available. The prices and covering capacities of Duresco black water paint are as follows :—

7 lb. tin (4*s.* 3*d.*), 225 sq. ft. minimum on glass.
¼ cwt. keg (13*s.* 6*d.*), 900 sq. ft. " "
1 cwt. keg (53*s.*), 3,600 sq. ft. " "

See also Chapter XIV.

An Official Memorandum (37) on the subject of lighting restrictions contains *inter alia* the following stipulations which in the event of war would be strictly enforced by the police :—

Private Houses, Shops, Business Premises and Places of Entertainment

All occupiers of premises used after dark would be required, for the duration of the war, to mask all windows, skylights and doors at night with dark blinds or curtains or other means, so that no light inside such premises was visible from outside. External lights would be forbidden.

Advertisement Lighting and Illuminated Signs

All illuminated advertisements and signs (other than signs installed specially for air raid precautions purposes) would be prohibited.

Factories and Industrial Premises

The emission of direct or reflected light from factory buildings would have to be prevented, normally by the screening of all windows and skylights with dark blinds or paint. External lighting would normally be prohibited.

Street Lighting

Normal street lighting would not be permitted in time of war. Traffic control signals, fitted with approved masking

devices, would be allowed to remain in operation in darkened streets.

Road Vehicles

Restrictions would be imposed on the lights carried by road vehicles. The use of motor car headlamps could only be allowed if they were heavily screened. Interior lighting in public vehicles would have to be obscured.

Railways

Lighting in trains and on railway premises would also be subject to restrictions. Details are being arranged with the railway companies.

Shipping, Navigation and Aircraft Lights

Shipping, navigation and aircraft lights would in general be controlled by arrangements made by the Government.

AIR RAID WARNING SIGNALS

Under the Air Raid Precautions Act, 1937, provisions for public general warnings in urban areas are made by—

County Councils,
County Borough Councils (and the Corporation of the City of London),
Metropolitan Borough Councils,
in England and Wales,
and County Councils,
Councils in cities and large burghs,
in Scotland.

The purpose of the signals is to give the general public warnings of air raids in urban areas. They take the form of a code of signals from any suitable sound source, such as

1. Steam sirens and whistles.
2. Compressed air sirens.
3. Self-generating rotary sirens.

A warning siren with a range of one mile—longer than any produced abroad—has been evolved.

The code must be adopted by public bodies and private establishments alike.

Air Raid Warnings

To give the public and services warning of impending raids, Britain is divided according to the telephone organisation into 100 comparatively small **Warning Districts,** each based on a Group Telephone Exchange. The districts do not coincide with the local government boundaries, so that a county may have different parts in two or more Warning Districts.

The warnings will be issued in turn to the Group Telephone Exchange of each Warning District threatened by a raid, and the warning will then be automatically distributed by telephone to recipients on pre-arranged Local **Warning Lists** (one **Special,** one **Action**) prepared by the Chief Constables.

The **Special Warning List** includes local A.R.P. Headquarters, Police and Fire Headquarters, First Aid Depots and Posts, public utility undertakings, blast furnaces (for damping down), and factories of national importance. The **Action List** includes, in addition, operators of Public Warning Signals.

GENERAL SCHEME OF AIR RAID WARNINGS

Preliminary Caution Telephone Code: " Yellow " (**Confidential**)	Confidential message to Government Departments and recipients on the local **Special Warning List,** that a raid on the district is likely in **about fifteen minutes.** A.R.P. services will take essential action as quietly and unobtrusively as possible, but no public warning will be given in case there is no raid.
Cancel Caution: Telephone Code " White " (**Confidential**).	If there is no raid, a message cancelling the Preliminary Caution will be sent to those who received it. Wardens will then be released from duty.
Action Warning: Telephone Code: " Red " (**Made Public**)	Recipients on the Special List and the additional recipients on the **Action List** are warned that a raid is possible in their district in 5–10 **minutes.** The Local Authorities concerned then issue warning signals to the public by hooter or sirens with a **fluctuating** or " **warbling** " or **intermittent blast,** the whole signal lasting two minutes. REPEATED ACTION WARNING.—All Wardens and police reinforce the general warning by sharp blasts of the **whistle** in their own Sectors. Public take necessary precautions and go to shelters; all traffic stops, and (if at night) all lights are put out.

Local Gas Warning: (To Public)	Wardens (or police) sound **hand rattles** continuously in any streets or areas affected by gas. An immediate report of the presence of gas in the locality is sent from the post to the Report Centre. *The Local Gas Warning must not be sounded more widely than is necessary, otherwise public and services will be unduly disorganised.*
Raiders Passed: Telephone Code: "Green" **(Made Public)**	Following a message from the National Warning Centre that raiders have left the district, the Local Authorities concerned issue a continuous **steady-pitched blast on sirens for two minutes** to advise public that raiders have left the district, or that a raid is no longer imminent. **This signal does not mean that any local gas danger is removed. Freedom from gas is indicated by the**
Local "All Clear": (To Public)	CANCEL GAS WARNING: Wardens, on instructions from their Chief or Head Warden, ring **handbells** through streets of their sector when all gas danger in that sector is removed. Group Warden or Head Warden advises Report Centre. If there has been no gas, the handbells are rung to reinforce the "Raiders Passed" signal.

Every householder and every Air Raid Warden must at once make himself acquainted with the exact details of the scheme of air raid warnings to be operated in his home district, and, if he works away from home, with the system to be operated near his place of business.

Training of A.R.P. Personnel

Too much emphasis cannot be laid upon the need for efficiency in all ranks of the A.R.P. services.

Apart from the Government training officially available[175] to selected employees (see p. 610) courses in Civil Defence are now organised in most universities and polytechnics.

Postal training is also available from the Correspondence Technical College, 91 Gower St., for the Examination Diploma of the Air Raid Protection Institute.

The examinations of this influential body are strongly recommended to A.R.P. officers, civil engineers, surveyors, architects, A.R.P. organisers, local authority officials and others who wish to acquire professional status in the highly specialised sphere of Civil Defence.

Postal courses are also available for the L.A.R.P. examination to the Home Office syllabus, as well as intensely practical courses in A.R.P.

For practical exercises and tactical training in A.R.P. the reader is referred to "Tactical Training in A.R.P. for Wardens and other Civil Defence Services," by Dr. S. E. Thomas.[174]

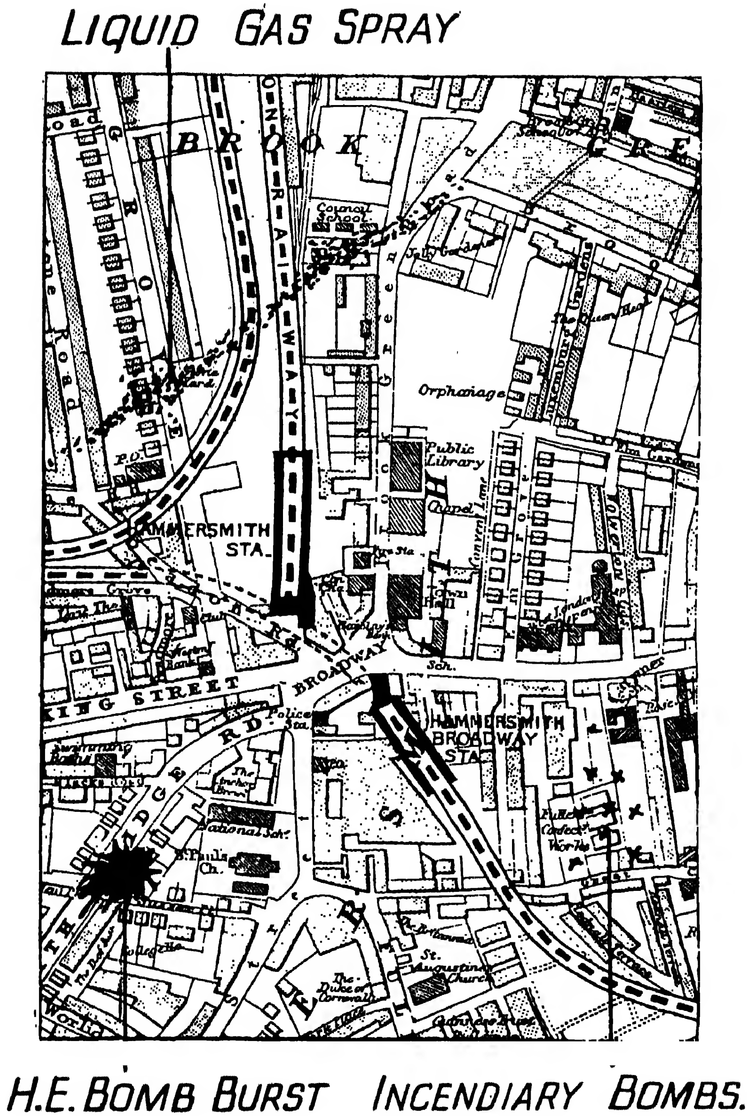


FIG. 300.—" Blots " on glass placed over maps facilitate indoor tactical exercises for A.R.P. personnel.

For indoor exercises on the reporting upon and the clearing up of any air raid incident, models such as that illustrated in Fig. 299 will be found of inestimable value. In using these models one of the trays supplied is filled with fine sand and levelled to the approximate contours of the sector to be illustrated.

Blocks of various shapes and sizes are then selected and arranged by the warden who learns his sector more intimately by the simple process of building it up.

Coloured cords are used to indicate different pipe-lines, cables, etc., and trees and shrubs are placed in position where required.

The chief warden creates realistic " incidents " by dropping steel " bombs " on the model, displacing buildings and forming craters—often over cables or mains. Incendiary bombs stay on buildings and " liquid spray " in the form of white powder, represents gas contamination.

The making of reports, the tabulation of the data, the issue of orders and the clearing up of the incident give all concerned at headquarters or depot indoor exercises invaluable in their training.

Another method that can be adopted for such indoor tactical games is to utilise a flat sheet of transparent celluloid or glass on which a number of " blots " of different colours and different sizes have been placed. This can then be placed by the instructor at random over the map of the sector and warden's reports made out in accordance with the indicated damage (see Fig. 300).

The Future

What of the future? To what extent will the air menace affect the planning of our cities and the design of our buildings? To what extent will communal activities and urban communities be modified to provide passive civil defence against air attack?

What easier target than a large metropolis like that shown in the upper portion of Fig. 301? Something has to be done about it!

From the earliest times military considerations of defence have had their influence in the planning of walled cities, and the weapons used and the methods of attack and defence dominated the design of every castle and manor house.

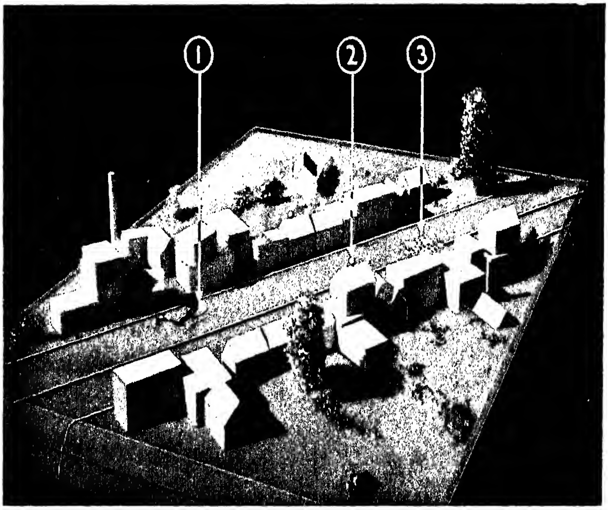


FIG. 299.—Model of a warden's sector showing air raid damage. (1) Structural damage from H.E. Transport destroyed, pedestrians injured and gas main severed. (2) Incendiary bombs. (3) Contamination by liquid gas.

(Courtesy Universal Air Defence Services.)

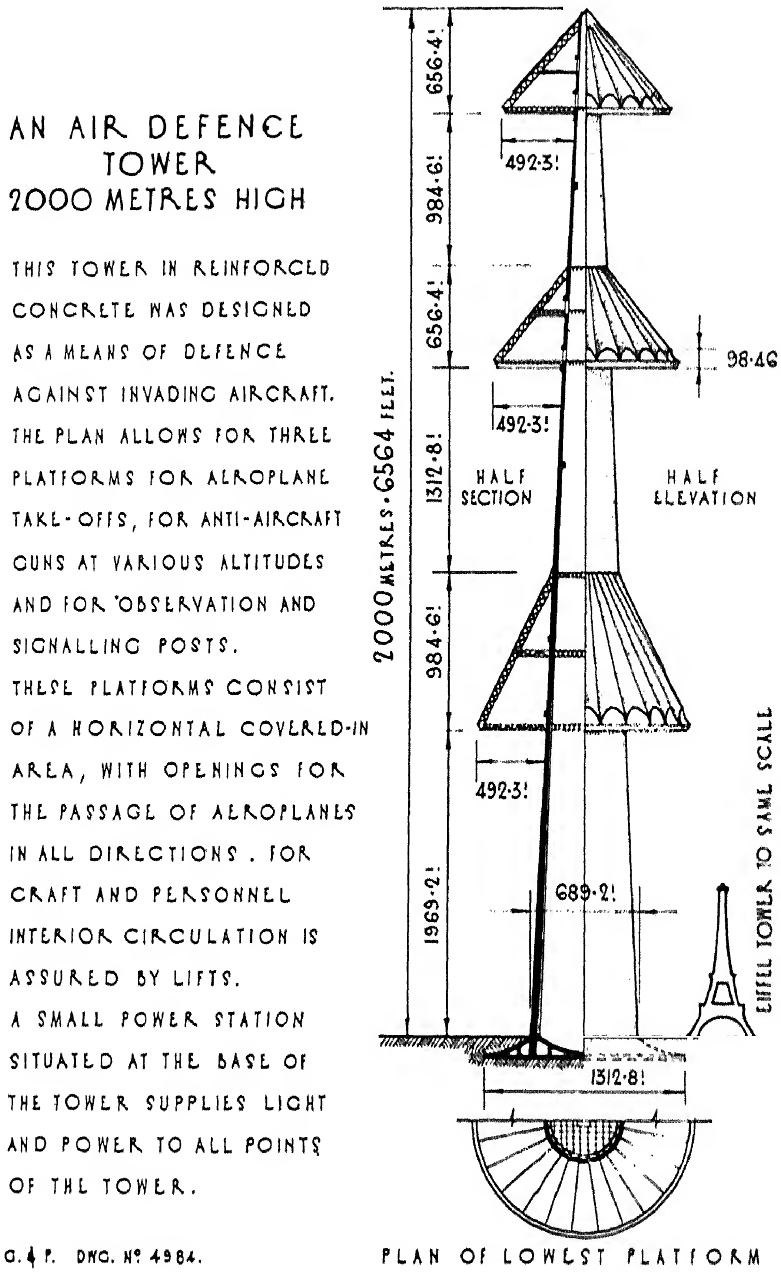


FIG. 299A.—A French project for an air defence tower.

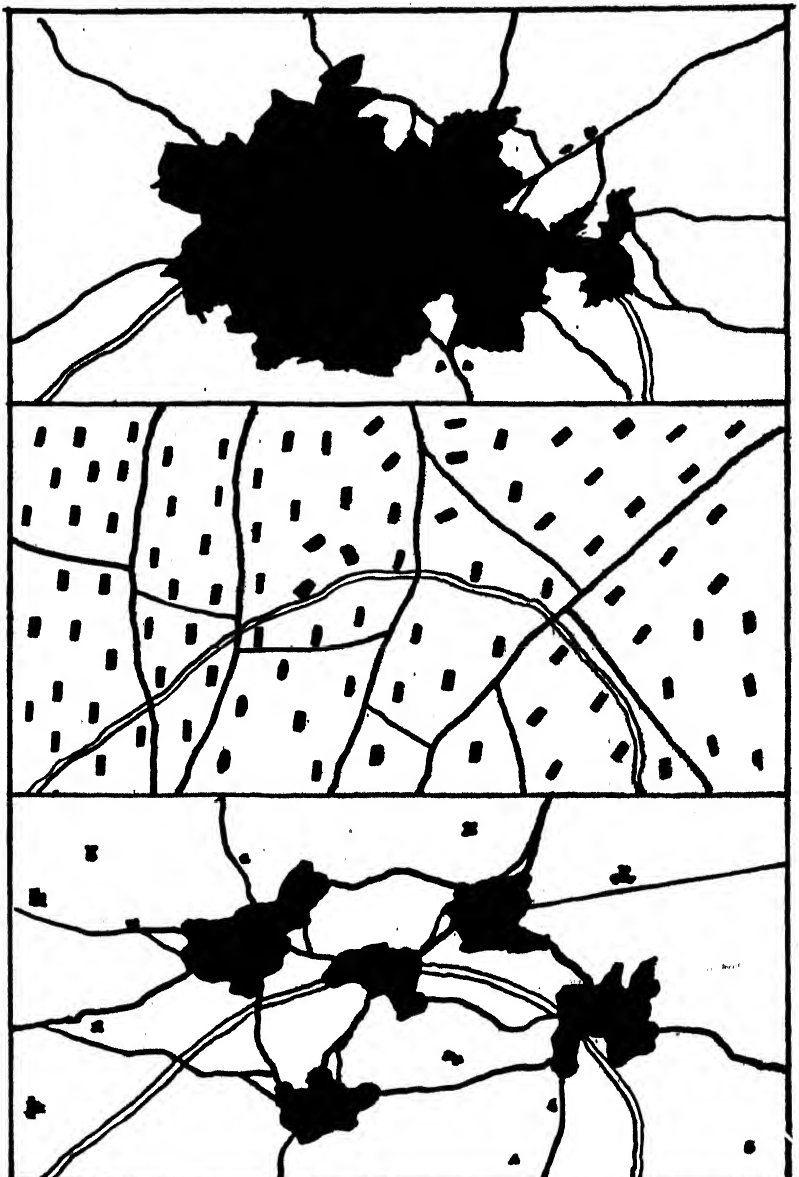


FIG. 301.—The influence of Civil Defence on town planning.
Upper Section; Large modern metropolis.
Middle Section; Back to the land!
Lower Section; Interconnected small towns.

Considerations of passive aerial defence are already influencing town planning, and the large city shown in the figure would, to a great extent, be evacuated in war.

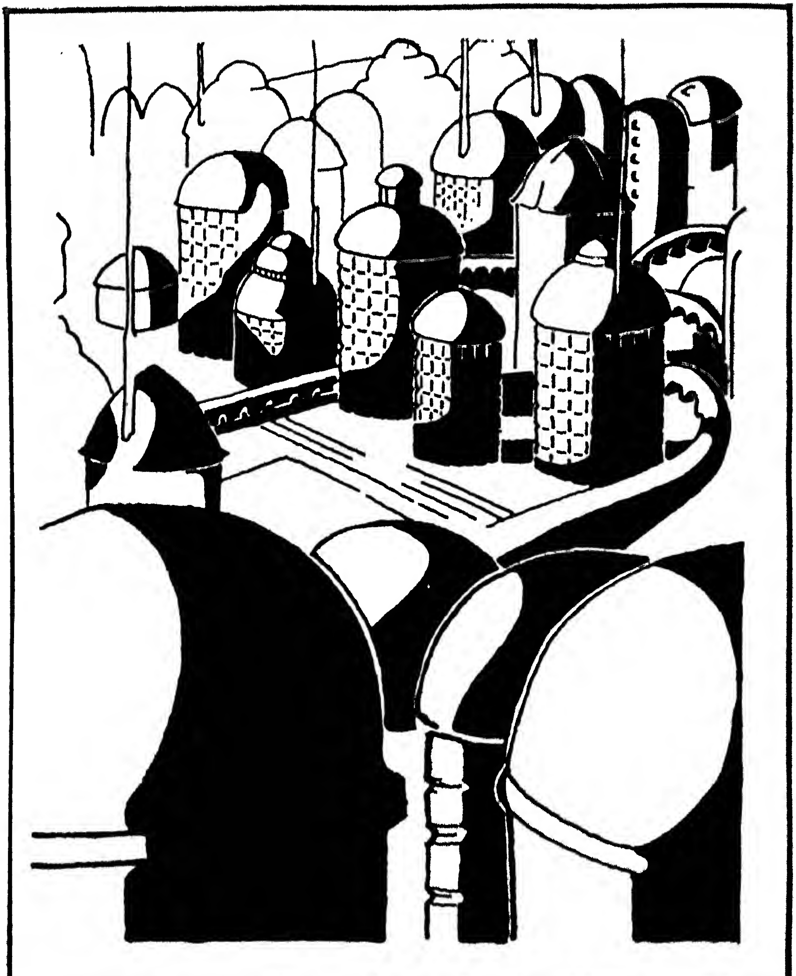


FIG. 302.—From a design by Professor Mariani for a town designed to resist aerial attack.

Alive to the advantages of dispersion a German author advocates "return to the land," and calculating upon the average intensity of human population in most European countries, amounting to one and a half persons per acre,

recommends the construction of homesteads for six persons on every four acres!

Such an arrangement is indicated in the middle of Fig. 301

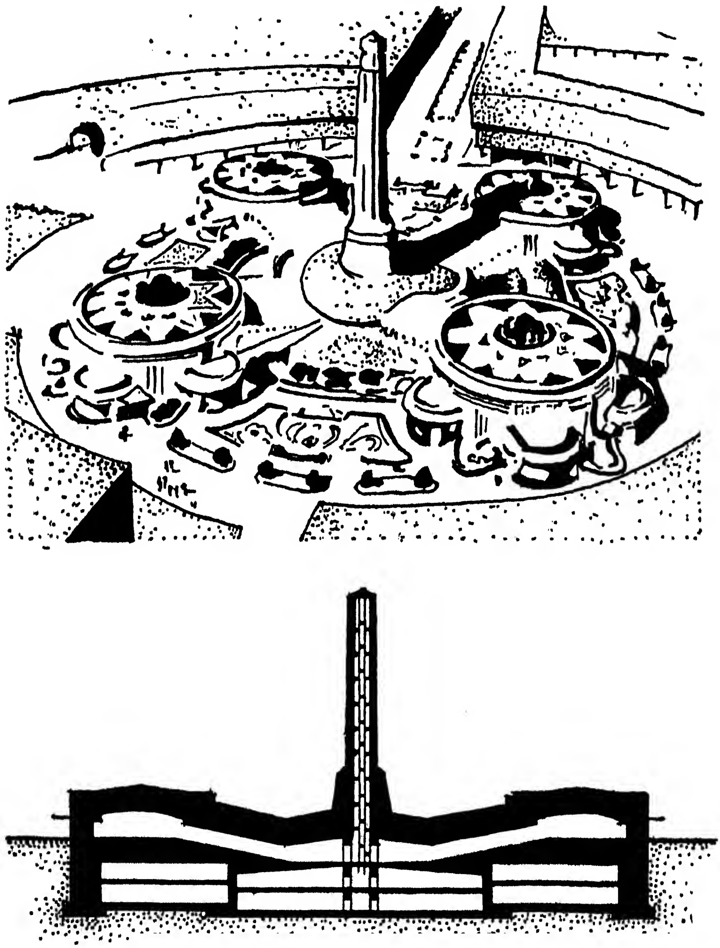


FIG. 303.—Communal activities in bomb-proof buildings in the city of the future!

and presupposes the complete cessation of most communal activities and the abandonment of the many advantages of urban planning for industry, business, recreation and pleasure!

The planning of interconnected self-contained towns of, say,

20,000 inhabitants combined with a considerable increase in the number of homesteads established in the countryside will probably be the logical development. (See bottom of Fig. 301.)

Consideration of Anti-Aircraft Defence and other military action will undoubtedly influence the planning of towns and the design and placing of large buildings near open spaces in the future.

Cities may be planned with glacis round them or at strategical points within the metropolis—Civil Defence providing hereafter a factor requiring constant consideration. A.R.P. is now one of the essentials in building design, as essential as lighting, heating and ventilation.

There is no doubt that considerations of passive aerial defence will influence the design of buildings in the future, and Fig. 302 shows a project by Professor Mariani for a community specially designed to resist aerial attack.

Note the circular planning of the buildings, the dome-like bomb deflecting types of roof and the covered approaches.

Whether the cities of the future will present such an appearance is a matter for considerable conjecture, but at an exhibition in Paris, showing air defence methods, not a few designers of vision showed such proposals.

A form of underground building designed by M. Jouven and eight collaborators is shown in Fig. 303.

Conceived upon a vast scale the scheme provides for communal activities in bomb proof independent buildings, connected together with underground establishments. Fig. 269 shows the author's proposals for the factory building of the future designed to provide Class 5 protection in the factory, and Class 6 protection in the adjoining store-cum-shelters.

By the arrangement proposed it will be seen that ordinary windows are not used and in their place blast-resisting lenses in reinforced concrete are utilised.

The flat top and sloping sides ensure freedom from tell-tale shadow and the earth-covered roof recovers for agriculture some of the lost acreage, provides automatic camouflage and protection against the incendiary bomb.

The hinged flaps over the panels of lens-crete are of use in camouflage and in blacking-out.

The cost of such a factory would be of the order of 15*s*. per sq. ft. of floor space.

CHAPTER XVIII

THE WAR

As pointed out in the Preface to the Third Edition, this section of the work goes to press when we have experienced twenty months of the war. The British Lion is at last aroused from its accustomed peaceful somnolency.

The armed forces of the Crown, often outnumbered and outclassed, have emerged triumphant through dogged determination under brilliant leadership, and although the assured material aid from the American continent has not yet fully matured, the tide is turning and the initiative in attack is now with the defenders of democracy and the enemies of aggression.

The defenceless peaceful civilian to whom this work is dedicated, has shouldered his war burdens—increased taxation, irksome defence regulations, rationing, long hours of national work, service in the volunteer civic organisations, lost sleep at the hands of the night bomber, and emerged from his shelter often to discover the complete destruction of his home and the loss of friends and relatives, but only to erect the Union Jack over the ruins and to resume his duties with added vigour and truly Churchillian determination.

Supporting a vigorous campaign in Africa, the Mediterranean and the Near East, and maintaining large defence armies in the British Isles, the British civilian calmly awaits invasion, endures continuous and ruthless bombardment from enemy air squadrons, joins his Home Guard unit and appoints his security police, the better to watch the nefarious activities of the treacherous Fifth Column in his midst.

Adequately to describe the courageous fortitude of the British civilian under bombardment from the air would tax the eulogy and encomium of a veritable laureate. Suffice it to say that neutral observers have described it as beyond panegyric praise.

The devastation caused by the bombing of the houses of the people has afforded practical proof of the necessity of providing for the demolition load on the roof of all indoor shelters (see pp. 203 *et seq.*).

Anderson Shelters have in innumerable instances saved the lives of the sheltering people whose houses within a few feet of the shelter have been demolished by bombs.

The maintenance of essential services, traffic, gas, water and electric supplies in the Metropolis throughout continuous aerial bombardment has been a constant source of amazement to the observer and particularly difficult reinstatements of services and sewers have been dealt with by bridging craters to avoid interruption in the traffic.

Gas

Up to the time of going to press, no belligerent in this war has yet used gas.

Nevertheless, gas protective measures are proceeding apace and the public are urged to ensure that shelters are made capable of being gas-proofed and respirators overhauled, kept in condition and always carried.

War Changes in Civil Defence

What changes has the war wrought on the technique of Civil Defence ?

The Civil Defence services have been mobilised on a war footing, and on the whole have come up to expectations in the grim reality of war work.

Happily the principles outlined in the foregoing pages written before the outbreak of the war and at the very inchoation of the science have withstood the acid test of inexorable experience.

New regulations have appeared to meet the changing needs of the time, but except where outlined in the following pages, the underlying technical principles have remained fundamentally intact.

Costs

Costs of building work and prices of equipment have experienced an understandable upward trend. For estimating

purposes it would be safe to allow an all round extra $33\frac{1}{3}$ per cent. on the costs given in earlier chapters in the volume, and except in special circumstances, of which the estimator would presumably have knowledge, the prices given may still be regarded as strictly comparable, having all been estimated upon a uniform basis.

Shelters

Experience has proved over and over again the wisdom of the policy of dispersion, and that, except where deep bomb-proof shelters are available, small shelters accommodating each a number not exceeding fifty persons and themselves presenting a *small* target, are preferable to larger ones.

In the early rush to provide shelters for all who could not be evacuated, underground shelters and those of the pill box type were constructed with little or no provision against waterproofing.

Many trench type shelters became flooded and unusable, and the use of shelters for sleeping accommodation in many cases became impossible.

As a result, subsequent waterproofing operations have had to be undertaken often at considerable cost and permanent drainage pumps installed in a number of cases.

The deep bomb-proof shelter has not been adopted to any great extent, but, subject to careful regulation, some Underground Railway Stations in London have been used as safe dormitories.

Work on branch tunnels at ten stations on the London Underground Railway has already begun with a view to providing deep shelters for 100,000 sleepers by the end of the summer of 1941.

The new tunnels, centrally situated, will be equipped with bunks, washing facilities, first-aid posts and provision will also be made therein for meals for the occupants.

They will be of use after the war as loop or branch lines.

Air Raid Shelters made from *Débris* Material

By the early spring of 1941 the large cities in this country had borne the brunt of aerial attack, but these are, generally speaking, better placed in regard to the shelter position than

are the satellite towns. These satellite towns are, unfortunately, overcrowded due to evacuation, and there is no doubt that in due course they will become target areas. It therefore behoves the authorities to encourage the construction of air raid shelters, and the object of the present suggestions is to indicate to the public how best they can help themselves in the present emergency.

The new indoor shelters (Fig. 304) known as the Morrison shelters and made in the form of a steel table, under which bedding can be placed, are to be a free issue, where needed, to families earning up to £350 per year. Those with higher incomes may be able to buy them for about £8 * *if* enough are available.

In any event, it will not be practicable in the early stages of distribution to cover anything like the whole country, and as a consequence priority areas will be established based upon experience of shelter needs and estimated vulnerability.

It will therefore be seen that the evacuee family and the "black coat" classes generally will have very largely to fend for themselves unless they decide at all times to make use of the public shelters which may be available.

Owing to the enhanced cost of building work, few can afford to have shelters specially built for private use, and the author therefore suggests that, by the proper utilisation of suitable *débris* material which can be made available by local authorities, all in need of shelters could with certain technical guidance construct, in their own homes, shelters giving Class 5 protection, *i.e.*, protection against all hazards except a direct hit, which is devastating and final, whatever precautions may be taken.

As an example of what may be done, Figs. 305 and 306 giving illustrations of shelters "F" have been selected from a range of specially prepared designs.

The advantage of indoor private shelters will readily be appreciated by any who have passed a night in an external shelter. The home comforts so much missed need not in the least be interfered with in an indoor shelter.

As has already been envisaged by officials and certain contractors who sell reinforced timber tables and reinforced concrete tables, the combined dining-room table-cum-shelter,

* March, 1941.

(Courtesy Ministry of Information)

FIG. 304.—Morrison Indoor Shelter.

[Facing p. 698.

under which a bed can be made, is likely to become very popular.

In these cases, however, considerable care must be taken to stand the shelter on a firm foundation. It is not sufficient to stand it merely upon the existing timber floor of a house, as in the event of the demolition of the house the shelter itself would in all probability be forced through the floor down to the ground or site concrete.

In some designs which the author has seen the legs of the table would themselves be forced through the boarding, thus reducing the space between the floor and the underside of the table top to a dangerous extent.

Furniture shelters which are at present obtainable vary in price from £9 19*s.* 6*d.** to £20.*

By careful attention to the instructions given below an enthusiastic householder could quite easily construct an entirely satisfactory shelter at a total cost of £5.*

In order to minimise the alterations to the building it is suggested that holes about 9 in. square be cut through the boards between the floor joists. Through these holes concrete pyramids can be formed, providing a solid support carried down to the site concrete, quite independent of the floor. The setting out dimensions are given on illustration Fig. 306.

A corner of a ground floor room is selected in order to take advantage of what resistance to splinters and blast is already provided by the existing walls. These walls should, however, be thickened out where shown to a total thickness of 14 in. of solid brickwork in order to provide for splinter protection in accordance with the structural code laid down by the Ministry of Home Security.

The other two walls of the shelter need be no thicker than 9 in. solid brickwork or masonry or concrete or whatever happens to be available. The combined resistance of this and that of the walls surrounding the room would provide the necessary splinter protection. A bomb falling actually within the room itself must be regarded as a direct hit, as protection against such a disaster would involve cost beyond the reach of the ordinary householder.

When the walls, which can be made of rubble masonry

* March, 1941.

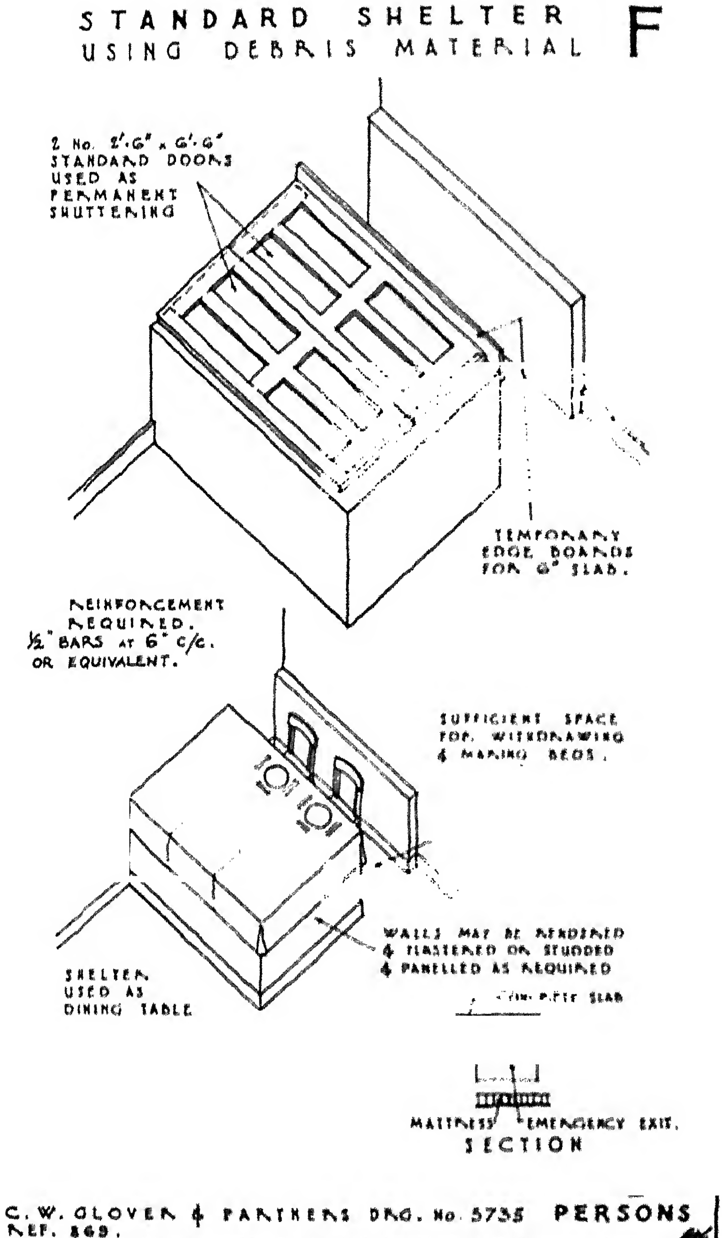


FIG. 305.—Fireproof indoor shelter.

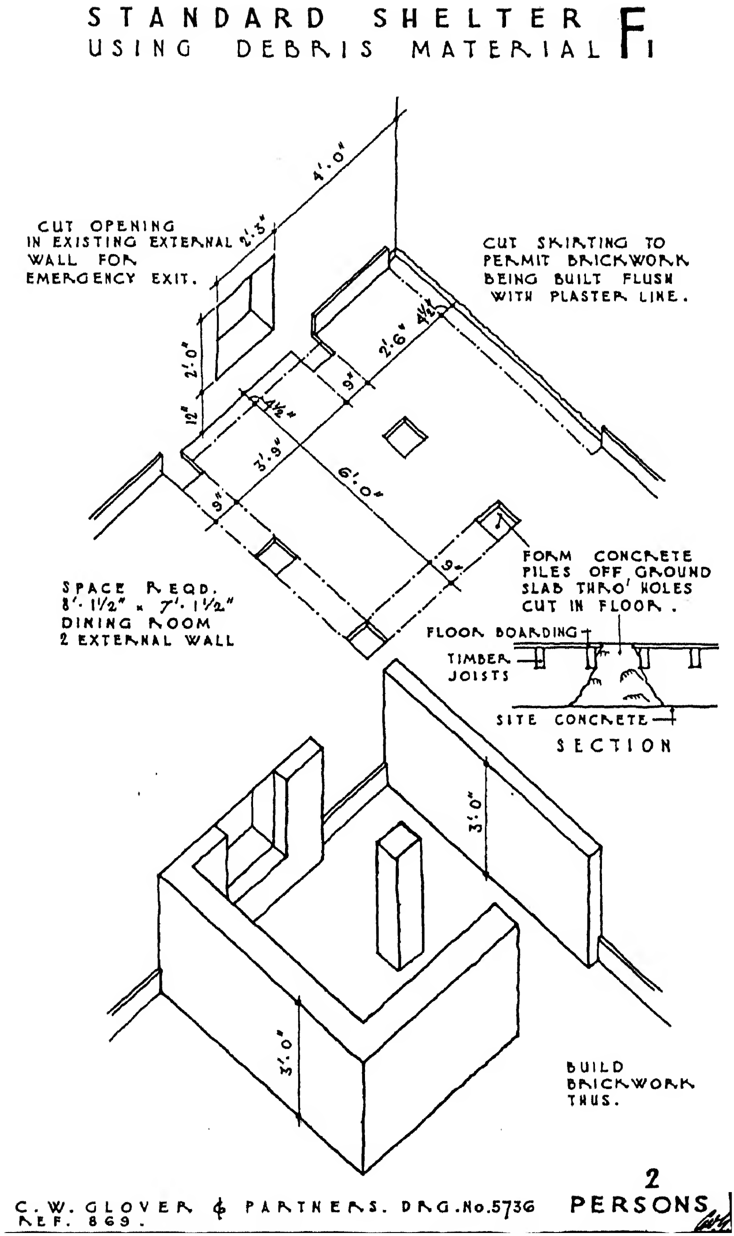


FIG. 306.—Setting out and construction of indoor shelter shown in Fig. 305.

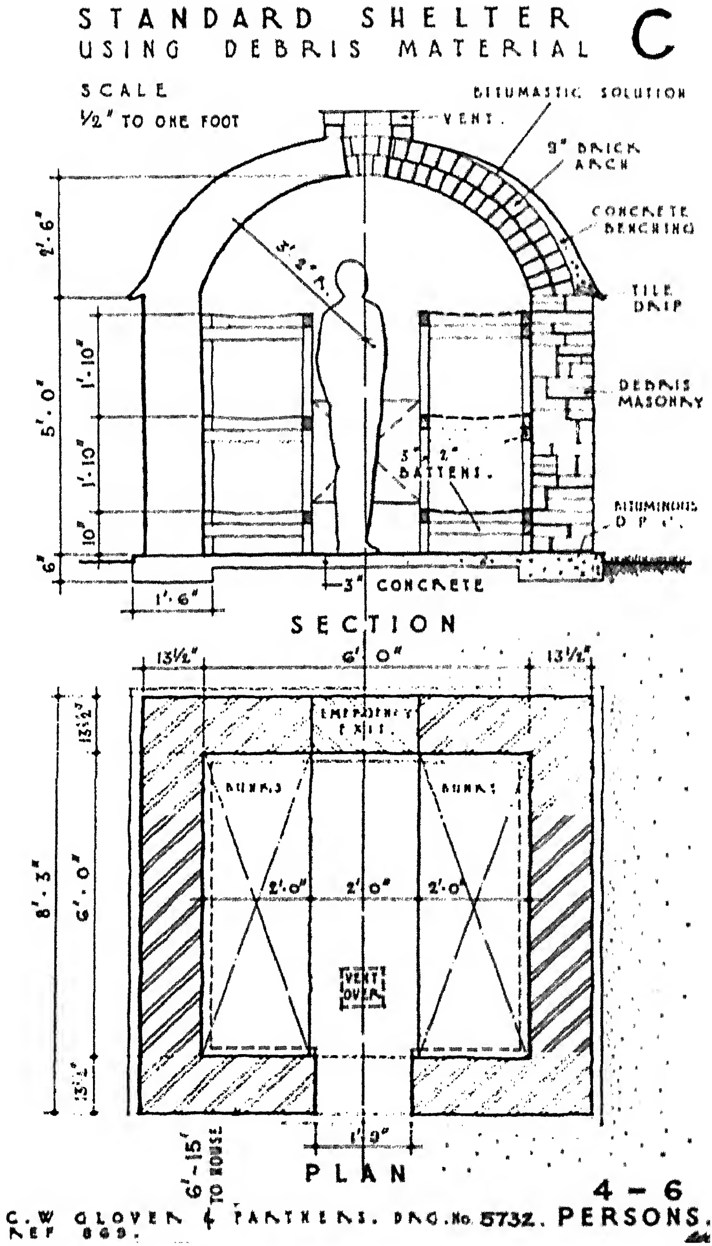


FIG. 307.—Outdoor shelter made of salvaged material.

from broken walls and the like obtainable from the *débris* dumps, have been constructed to a height of 3 ft. the roof can be formed in reinforced concrete on permanent shuttering of old doors or the like. These would ultimately provide thermal insulation and prevent condensation on the underside of the slab. Old railings or bars could be used for reinforcement and the concrete could be made from crushed brick and Portland cement, or preferably from ballast, sand and cement in proportions of 4 : 2 : 1.

It is not suggested that the ordinary householder should execute the whole of this work by himself without any expert guidance. Indeed, it is at this stage that experts would be of most help to him. One reliable skilled artisan could well deal with the construction of about a dozen such shelters simultaneously, provided the householders themselves supplied the necessary rough labour or arranged to employ such assistance as might be necessary.

Local builders, with the guidance of a competent designer, could well establish a corps of experts who could provide the guidance householders would require. Thus without burdening the existing overworked A.R.P. Municipal Services, local building interests could well serve the public by undertaking the expert guidance of the householder in the provision of furniture shelters at present so badly needed, especially in the smaller towns throughout the country.

The only new material that would be required in the construction of any of these indoor shelters would be Portland cement. This can now be obtained without a special certificate. The whole of the rest of the material would be obtainable from the dumps of *débris*, which unfortunately are accumulating in all big cities, and which can well be utilised for this purpose.

Much can be done in this matter by courageous self-help, but expert guidance in the selection and arrangement of the reinforcement in the top slab is of utmost importance and careful attention to the practical hints made by supervisors would ensure soundness of the finished work.

In the light of the experience of the construction of some thousands of shelters of all kinds the author has been struck by the almost universal demand for a service such as is envisaged above.

Fire

As in the Great War of 1914–18 the enemy has made a determined effort to set fire to London. Some effects are to be seen in the frontispiece, a photograph taken from St. Paul's showing part of the City after a fire blitz.

In order to supplement the personnel of the established fire brigades and the A.F.S. the public are now called upon to take turns at fire watching duties.

FIRE WATCHING AND COMPULSORY SERVICE IN CIVIL DEFENCE

Generally

Occupiers of business premises are bound to make arrangements for fire watching. Workers in business premises are obliged to undertake fire watching duties at their places of employment. Residents are liable to be enrolled compulsorily as fire watchers.

Compulsory Fire Watching

Compulsory fire watching is provided for under Regulations 26A, 27A, 27B and 38 of the Defence (General) Regulations, 1939, and Orders and Directions made or given under those Regulations.

The Orders made to date are :—

The Fire Watchers Order No. 1677 (September 19th, 1940).

General Regulations Order No. 68 (January 15th, 1941).

Fire Prevention (Business Premises) Order No. 69 (January 18th, 1941).

And the Civil Defence Duties (Compulsory Enrolment) Order No. 70 (January 18th, 1941).

The Regulations provide for :—

(*a*) Compulsory arrangements for fire watching at business premises.

(*b*) Compulsory performance of part-time civil defence duties.

Civil Defence Duties

Order No. 68, 1941, affords the Minister of Home Security general powers to require all British subjects of either sex

between the ages of sixteen and sixty to register and to be enrolled compulsorily for part-time unpaid civil defence duties in the area in which they reside.

At the present time only persons of the male sex are liable to be compulsorily enrolled and then only for the performance of fire prevention duties in order to enable local councils to carry out their duty of making arrangements for securing that a watch is kept for the fall of incendiary bombs in the area of the council, that all practicable steps are taken immediately to deal with fires caused by such bombs, and that assistance is summoned as necessary.

The areas in which civil defence is compulsory will be those in which the local councils are unable to find sufficient volunteers to carry out the fire prevention duties imposed upon them. Persons failing to register are liable, on conviction before a magistrate to imprisonment for a term not exceeding three months or to a fine not exceeding £100 or to both.

A person enrolled may only be required to do forty-eight hours' duty in any calendar month.

A person who refuses to do duty is liable, on conviction before a magistrate to imprisonment for a term not exceeding three months or to a fine not exceeding £100 or to both.

Exempted Classes of Persons

1. A member of the armed forces of the Crown.
2. A member of the Home Guard.
3. A constable, including a special constable.
4. A person of unsound mind.
5. A registered blind person.
6. A civil defence volunteer.
7. Any other class which may be prescribed by the Minister of Home Security, or a Regional Commissioner.

Fire Watchers in Business Premises

The premises for which arrangements for fire watching are to be made are business premises, that is, any premises occupied wholly or partly for the purpose of any business, trade or profession, which are situate in any area prescribed by the Minister of Home Security or by a Regional Commissioner.

Premises which are occupied by a person partly as his dwelling house and partly for the purposes of his business, trade or profession are exempt.

Occupiers of business premises are required to make proper and adequate arrangements to secure that fires occurring at the premises as a result of hostile attack will be immediately detected and dealt with.

Arrangements for dealing with fires must secure :—

(*a*) That an adequate number of persons for the purpose of discharging fire prevention duties are at all times present at the premises.

(*b*) That specified fire prevention duties are allotted to those persons.

(*c*) That adequate fire prevention equipment is at all times available at the premises.

"Fire prevention duties" means the duties of keeping a watch for the fall of incendiary bombs, taking such steps as are immediately practicable to combat a fire caused by such bombs and summoning such assistance as may be necessary, and includes the duty of being in readiness to perform any such duties.

The fire watcher must :—

(*a*) Be present on the premises at all times during which he has undertaken to act as fire watcher ; and

(*b*) During a period in which hostile attack is in progress in the vicinity or an air raid warning is in operation, be in readiness to detect outbreaks of fire and to summon assistance and to use such fire-fighting appliances as may be available. An air raid warning is assumed to last from the giving of a public air raid warning signal to the giving of a public raiders' passed signal.

Arrangements made must be notified in writing to the appropriate authority within fourteen days of the date when the obligation to make arrangements arises.

Fig. 308 depicts fire-fighting methods for dealing with the incendiary bomb menace in office buildings as organised by the fire protection services of the City of Westminster.

A typical fire squad consists of six trained men under the command of a leader and is always on duty during a day or night "alert."

All men are trained in the use of fire-fighting appliances and must know the way about all parts of the building. Two men are always on patrol and the remainder are ready for instant action.

The respective duties are depicted on the illustration, but should an incendiary bomb enter the building or land on the roof one of the patrol immediately tackles it, and his mate, having called for help, goes to his aid.

The fire brigades are only called if the conflagration gets out of hand, but the fire watchers in each building can best deal with the incendiary bomb and usually are able to get it under control without further assistance.

Fig. 309 indicates the organisation of fire-fighting precautions in residential districts with a view to dealing with the incendiary bomb before it can start a fire.

Group leaders should take a fire-fighting course and thereafter train their own groups. Stirrup pumps, ladders, sand, water and shovels should be disposed generally as indicated on the illustration and householders should co-operate to the extent of taking the precautions indicated in the inset figure.

During an "alert" the "watch" usually lasts two hours, but in urgent cases may last for the duration of the raid.

Glass

Recent raids have shown the importance of preventing broken glass from being scattered by blast. Nothing stuck on glass will make any material difference in the amount of glass broken by blast; nor can any simple bracing system help matters. Glass in windows and doors is less liable to fracture by blast when they are as wide open as possible.

It is generally accepted that in the open country all usual types of glazing up to 26 oz. are liable to be shattered by blast from a 500 lb. H.E. bomb exploding within a distance of 300 yards—a glass shattering area of 283,000 sq. yds. (over 58 acres in extent).

Bombing experiences have demonstrated that an H.E. bomb falling in a densely built up area will cause but localised damage due to the screening effects of surrounding buildings.

On the other hand, narrow streets often produce a tunnel effect to blast pressure which is thus transmitted to a greatly

increased distance there to encompass damage of a surprising extent—often known as a freak effect.

Actual experience of bombing indicates that neglecting abnormal freak effects, the radius at which blast from a 500 lb. H.E. bomb will shatter normal window glazing in a city is nearer 70 yds.

In carrying out comparative blast tests on glass Captain C. G. Brasher used test bombs consisting of 2 lb. charges of blasting powder of an approximate composition of 15 per cent. T.N.T., 80 per cent. ammonium nitrate, and 5 per cent. barium nitrate, contained in round glass flasks resting on 3 in. cast-steel tables placed at various distances from the target. In every case the flasks disintegrated so completely that there were no signs of splinters on the targets. The force of the explosions was such as to break up the tables on which the bombs rested.

The distances of the bombs were said to be approximately the equivalent of a 500 lb. H.E. bomb at the ranges shown below :—

Distance of test bomb from target.	Equivalent range of 500 lb. H.E. bomb.
50 ft.	250–200 yds.
40 ,,	200–160 ,,
30 ,,	150–120 ,,
20 ,,	100– 80 ,,
10 ,,	50– 40 ,,

The tests were carried out on two windows glazed with a total of twenty-five panes of glass of which one was ordinary sheet glass unprotected in any way. The results of different methods of protection were studied in comparison with this pane.

The full results were published in the *Journal of the Air Raid Protection Institute*, published in April, 1940, and to this the interested reader is referred.

Concluding his report, Captain Brasher makes the following interesting suggestions :—

1. Comparing results in the two windows, it appears that the smaller panes, even if of thinner glass, are more resistant. This is interesting from the household point of view, since in general the smaller the house, the smaller the windows.

2. The quality and weight of the glass is important, as is

shown by No. 2 (32 oz.), which resisted unprotected after its neighbours (protected) had been broken.

3. There is evidence that, to a limited extent, protection by paper, cellophane and surgical tape is effective in retaining splinters, provided that it is carried over the frame to give it an anchorage. Of these methods, cellophane strips and surgical tape appear to be the most effective.

4. More solid forms of protection, such as complete sheets of stout paper, millboard, or, preferably shutters, which, while they obscure light (in the case of shuttering, temporarily) are, on the whole, effective.

Protection of Vertical Windows

The scattering of broken glass can be reduced by :—

1. Covering windows with wire netting of ½ in. or smaller mesh.

2. Covering windows with internal light-weight screens, fitted close to the glass.

3. Anti-scatter treatment.

(*a*) *Generally*. Panes of glass properly covered by adhesive " anti-scatter " treatment will remain in place under mild blast even if badly cracked. Strong textile netting or other fabrics if firmly stuck to the glass afford good " anti-scatter " protection. Cellulose film, whether plain or self-adhesive, is affected by moisture ; a coat of good varnish applied as a water-proofing over the film helps considerably.

Strips of material spaced apart can be used with good effect, but the closer the spacing the better. The strips should preferably be not less than 1½ in. wide, spaced with not more than 6 in. of clear glass between.

A liquid coating is not expected to give effective anti-scatter protection on panes more than 4 sq. ft. in area. This class includes rubber latex, compositions containing rubber latex, with or without a sealing coat and synthetic resins. These materials are easy to apply, but they are liable to lose their protective value when exposed to sunlight.

Before treatment is applied the glass should be clean and free from oil or grease.

(*b*) *Textile Materials.* Nettings can be obtained either plain or ready-treated with adhesive. With the latter

(i) Dip the netting in water for one or two seconds only, then shake out the excess water and apply the net to the glass, or

(ii) Moisten the netting by spreading it on a wet cloth, or

(iii) Wet the glass, and then apply the dry netting, patting it into place with a wet cloth.

The material should be cut large enough to allow for shrinkage and to permit of it being carried over the frames and stuck to them as well as the glass.

Plain ungummed netting can be affixed with any convenient strong adhesive, *e.g.*, cold water paste, flour paste or gum. The adhesive is brushed freely on the glass and the netting pressed on. If the window is one which is exposed to hot sunshine, the addition of a little glycerine (say 5 per cent.) to the adhesive will help to prevent it from drying out completely and becoming brittle.

A stronger and also a more waterproof job can be made by bedding the netting in a good elastic varnish; a full coat of varnish is brushed on the glass, allowed to get tacky and the netting applied. Finally, a further coat of varnish is applied over the whole area.

The following nettings have been approved on the basis of tests :—

Name and Address of Makers.	Number or Designation of Nettings Approved
R. E. Ashworth & Co. Ltd., 37 Stoney Street, Nottingham.	(i) " Sunenta " large squares. (ii) ,, small squares. (iii) ,, patterned squares.
Wallis Binch, New Basford, Nottingham.	(i) No. 22. (ii) No. 7682.
Black Bros. Ltd., Stoney Street, Manchester.	Anti-splinter net.
Carey & Sons Ltd., 45 Broad Street, Nottingham.	Splinter-proof nets, Nos. 9643, 027743, 22, 810573, 0210135.
Ed. Cope & Co. Ltd., High Church Street, New Basford, Nottingham.	No. 72 or No. 147.
Daybrook Fabrics Ltd., Young's Factory, Alfred Street South, Nottingham.	(i) Dessanita Quality, No. 1. (ii) ,, ,, ,, 2.
John Dickenson & Co. Ltd., Home Park Mills, Kings Langley, Herts.	" Splinternet."

Name and Address of Makers.	Number or Designation of Nettings Approved.
Dobson & M. Browne & Co. Ltd., DelBeta House, Nottingham.	(i) No. GF3698. (ii) ,, GF3958. (iii) ,, 10489–GF3169½.
Frymann & Fletcher Ltd., Clyde Works, Denison Street, Nottingham.	Splinter-proof nets. No. 75894. ,, 75803. ,, 75763.
M. Jacoby & Co. Ltd., Nottingham.	No. 9387.
Alexr. Jamieson & Co. Ltd., Darvel, Ayrshire.	No. 7505.
Harry Johnson (Nottingham) Ltd., 38 St. Mary's Gate, Nottingham.	No. 4508.
Key A.R.P. Products, Keystone House, Adeline Place, W.C.1.	Splinter-proof white netting.
W. J. & T. Lambert & Co. Ltd., Talbot Street, Nottingham.	(i) Back glued net. (ii) Impregnated net. (iii) Mosquito net.
Levin Bros. & Co. Ltd., Middle Pavement, Nottingham.	(i) No. 9061. (ii) ,, 9062.
Alex. Morton & Co. Ltd., Darvel, Ayrshire.	Anti-splinter nets. Nos. 70, 70/1.
R. Newbold, Kayes Walk, Nottingham.	Anti-splinter, anti-dazzle.
A. & F. H. Parkes (Nottingham) Ltd., Anglo-Scotian Mills, Beeston, Notts.	" Nuart " anti-splinter net.
C. & J. Robertson Ltd., Ladeside Factories, Glaston, Ayrshire.	(i) No. AS1. (ii) ,, AS250.
Stirling Bros. & Co. Ltd., Darvel, Ayrshire.	(i) No. 14960. (ii) ,, 34961/X.
Frank Tatham Ltd., 12 Plumtree Street, Nottingham.	No. 252.
L. O. Trivett Ltd., Trivetts Buildings, Short Hill, Nottingham.	(i) No. A4558. (ii) ,, A4559.
Wallace & Co. (Netherplace) Ltd., Netherplace, Newton Mearns, Nr. Glasgow.	(i) No. A1. (ii) ,, A2.
George Walton & Sons, High Pavement, Sutton-in-Ashfield.	Anti-splinter net.
J. & J. Wilson & Co. Ltd., Greenhead Mills, Newmilns, Ayrshire.	A.R.P. Nets. Nos. 830, 836, 8694A, 9061.
A. Herbert Wooley & Co. Ltd., Nottingham.	(i) No. 0800/1. (ii) ,, 0801/1. (iii) ,, 0802/1.

All the above nettings were supplied ready treated with adhesive.

The following untreated netting tested in conjunction with various separate adhesives gave satisfactory results :—

Whiteley, Stevens & Co. Ltd., Stapleford, Nr. Nottingham.	No. 6152.

The following nettings tested in conjunction with special varnishes or lacquers supplied with them for use both as the adhesive and as a subsequent coating were found to be satisfactory.

1. Beaver Anti-splinter Varnish and Netting
   Beaver Paint Co. Ltd., 20 Tithebarn Street, Liverpool 2.
2. Cerrux Shatter-resisting Varnish S.3615 and Reinforcing Fabrics, Nos. 1, 2 and 3
   Cellon Ltd., Kingston-on-Thames.
3. Anti-splinter Lacquer and Netting
   A. Holden & Sons Ltd., Bordesley Green Road, Birmingham 9.
4. Foochow Shatterproof Compound and Netting
   Donald Macpherson & Co. Ltd., 21 Albion Street, Manchester.

(c) Transparent Films

(i) The following materials have been approved after test by the B.R.S. :—

1. "Celilynd" . British Celilynd Ltd., Burwell Works, Lea Bridge, Leyton, E.10.

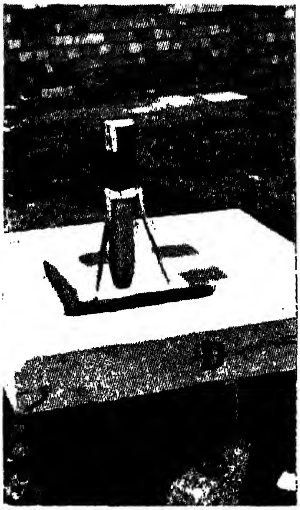
(In this case the film was reinforced with light textile netting.)

2. "Cellophane" . British Cellophane Ltd., 17–19 Stratford Place, W.1.
3. "Diophane" Transparent Paper Co., Bury, Lancs.
4. "Rayophane" . British Rayophane Ltd., Wigton, Cumberland.
5. "Sidac" . . British Sidac Ltd., St. Helens, Lancs.

The thickness of the cellulose film should be of not less substance than 60 gm. per sq. metre. It is important that the adhesive be flexible. Ordinary liquid gum can be used if glycerine or treacle is added in the proportion of about 1 teaspoonful to 2 tablespoonfuls of gum. The adhesive should be brushed on the glass and the dry film applied with a roller, preferably in strips, say 4 in. wide, and placed side by side.

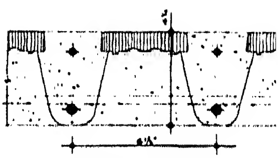
(ii) *Self-adhesive Cellulose Film.* The following materials have been approved :—

1. "A.R.P. Window Tape" British Cellophane Ltd., 17–19 Stratford Place, W.1.

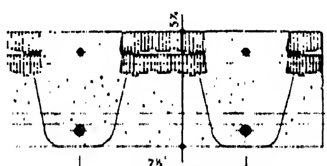


ROOF LIGHTS (Type 16 and 16/16).

Incendiary bomb tests were carried out on the single and double types in the following manner. The Lens on which the bomb stood in both cases was starred by drilling to represent the fracture caused by impact of the 2 lb. bomb at 400-500 ft. secs. and in the double lens construction the lower lens was also starred to give the most severe test. An Elektron bomb was then placed on the damaged lens, ignited and allowed to burn out. The effect on the lens was negligible and no change in its condition was observed. The construction remained gas-proof.



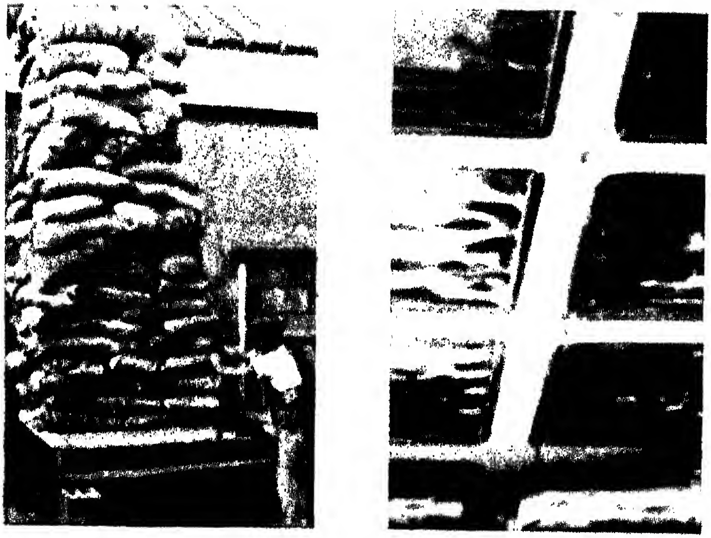
A.R.P. 16/425.



A.R.P.-1616/525.

(Courtesy J. A. King & Co.)

FIG. 310.—Incendiary bomb test on Glascrete construction.



LAMINATED GLASS BRICK WINDOW (Type 88 88).

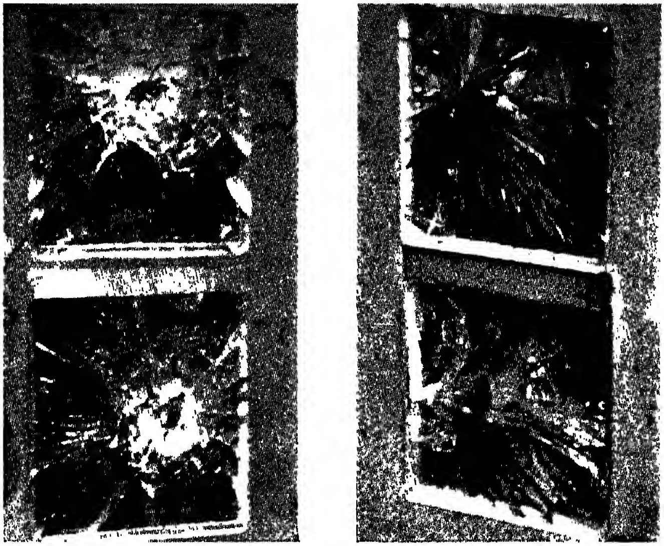
With a view to ascertaining the behaviour of this construction under dead loading conditions. A panel 4' 0" x 4' 0" supported on R. S. J.s on four sides was loaded with cwt. cement sacks and deflection readings taken. Test was limited to five tons due to the difficulty of erecting the cement sacks. Photograph on the left shows panel fully loaded and that on the right small cracks which developed on the underside when the R.S.J. support was removed on one side.

Ultimate failure occurred when two side supports were removed.

Deflection with one ton—.05 of inch.
Deflection with five tons—.23 of inch.

(Courtesy J. A. King.)

FIG. 311. Loading test on Glascrete construction



LAMINATED GLASS BRICK WINDOW. (Type 88/88).

The object of this test was to discover the degree of resistance afforded by the type of construction against small projectiles, splinters and debris.

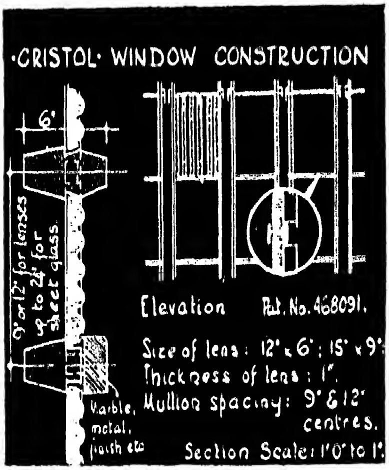
The test was carried out with a .303 mark VII cartridge fired from a standard army rifle at 30 yards range, the bullets flattened completely on the lens surfaces and both the front and back glasses were cracked in each trial. In neither case, however, was there any glass dislodged from the back of the panel. The construction remained gas-proof.

The depth of penetration of the bullet was between $\frac{1}{8}''$ and $\frac{3}{16}''$ —the striking force of the projectile was approximately 2200-ft. lbs.—nine times that of a standard .45 revolver bullet.

This construction provides a high degree of protection against machine gun fire from low flying aircraft. Photographs show front lens (left) and back lens (right) after test.

(*Courtesy J. A. King & Co.*)

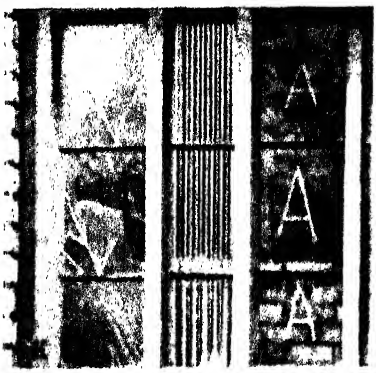
Fig. 312.—Impact test on laminated glass brick window.



BLAST RESISTING

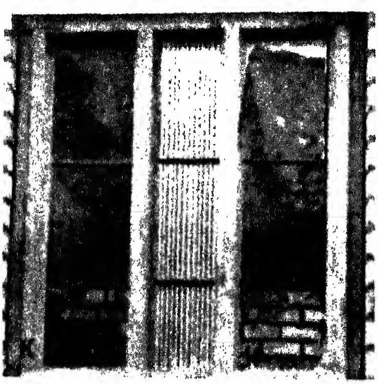
Cristol Window Construction (Type 222)

This type of window consists of a series of vertical reinforced concrete mullions grooved and slotted to receive H members which in turn provide positive support for each glass unit. On test, bars withstood a stress of over 15 tons per bar without fracture. This construction permits windows to be built to any desired size.



BLAST equal to 500-lb. BOMB at 80 yds. at 40 yds.

Georgian wired units, left three, cracked by first blast and dislodged by second blast. Pressed lenses centre unaffected by first and second blasts. "Armourplate" units, right, unaffected by first blast but centre unit blown out undamaged by second blast.

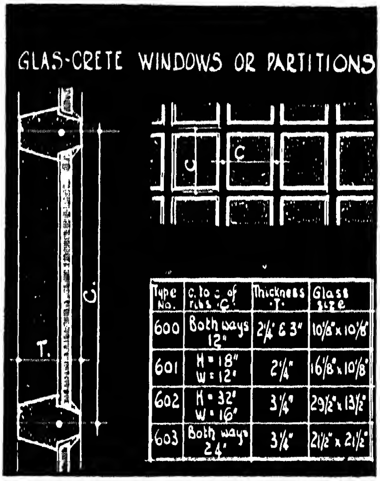


BLAST equal to 500-lb. BOMB at 24 yds.

Remainder of wired glass and "Armourplate" shattered, fragments falling 30 ft backwards and 15 ft forwards. Early failure of wired glass and "Armourplate" due to lightness of metal H sections. Pressed lenses undamaged.

(Courtesy J. A. King & Co.)

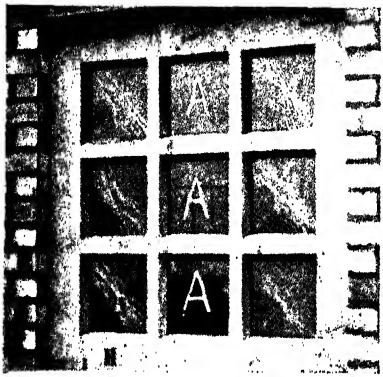
FIG. 313. Blast tests on Glascrete construction.



BLAST RESISTING

Grid Window Construction (Types 600)

This construction consists of a series of vertical and horizontal exposed reinforced concrete ribs with glazing. Areas of any size can be built up in a number of units. Glazing, wired glass or armoured plate should be used. Opening lights or ventilators can be introduced where required. These may be either the usual type or gas tight pattern.



BLAST equal to 500-lb. BOMB at 40 yds.

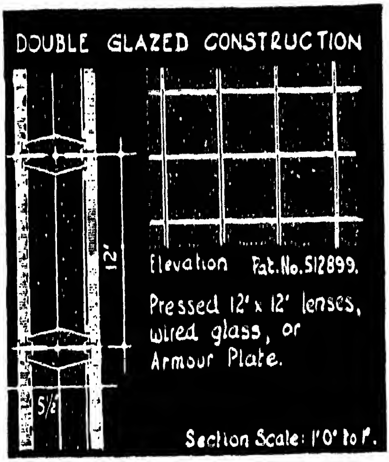
Georgian wired, left three, and wired units, right three, cracked. No glass dislodged. "Armourplate" units, centre, undamaged. Slight displacement of brickwork.

BLAST equal to 500-lb. BOMB at 24 yds.

Georgian wired units blown in to a distance of 6 ft. Wired units broken but hanging. "Armourplate" units entirely undamaged. Slight cracking at back of frame at six points.

(*Courtesy J. A. King & Co.*)

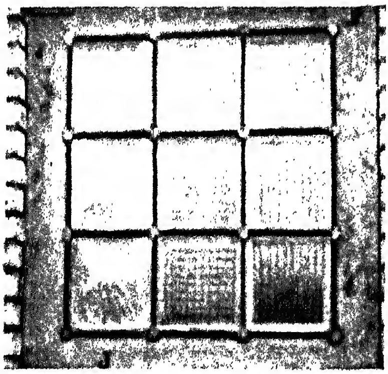
FIG. 314.—Blast tests on Glascrete construction.



BLAST RESISTING

Double Glass and Load-bearing Concrete Construction (Type 1212)

A construction comprising a reinforced concrete grid. To both sides glass plates are fixed. Can be constructed to indefinite height and width and will normally carry the weight of its own thickness of brickwork.



BLAST equal to 500-lb. BOMB at 40 yds.

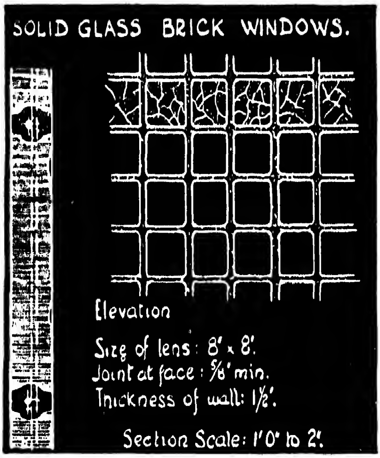
Georgian wired, left three, cracked outwards radially. None of the glass fell away. Slight shelling of pressed lenses, due to inadequate cushioning. Rear glazing undamaged.

BLAST equal to 500-lb. BOMB at 24 yds.

Georgian wired, left three, sucked outwards and fragments fell. Georgian wired at back cracked. Five pressed lenses at front broken and two at back cracked. "Armourplate" lenses at back, right, undamaged.

(Courtesy J. A. King.)

FIG. 315.—Blast tests on Glascrete construction



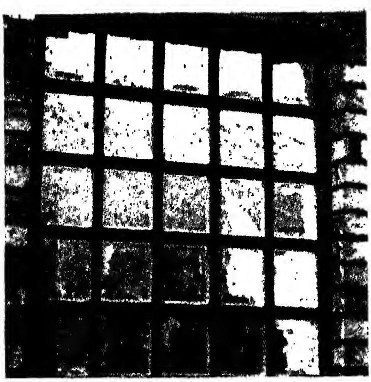
BLAST RESISTING

Solid Glass Brick Construction (Type 88).

The lenses 8 in. by 8 in. plain on one side and Flemish pattern on the other. The sides of the lenses are rebated to provide horizontal and vertical keyed channels in which concrete and reinforcing rods are used to form structural members.

BLAST equal to 500-lb. BOMB at 16 yds.

Slight shelling of one lens and pitting from bomb case otherwise all lenses undamaged. Slight cracking of concrete framing probably due to method of clamping frame at top and bottom only.



NO FURTHER TEST.

As it was decided that the limit of safety was reached in the first test no further test was conducted on this panel. Illustration shows undamaged rear face.

(*Courtesy J. A. King & Co.*)

FIG. 316.—Blast test on Glascrete construction.

BLAST AND SPLINTER RESISTING

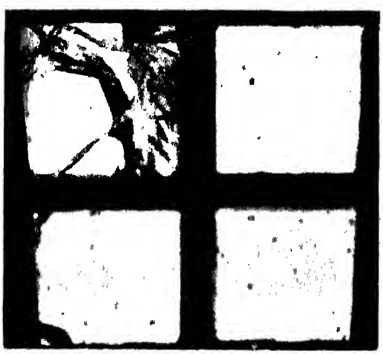
Solid Glass Brick Construction (Type 88 AP).

Lenses 8 in. by 8 in. plain one face, Flemish pattern exterior face. "Armourplate" fixed by special process to inner face to minimise danger of shelling under impact from steel splinters and debris. Type 88 fixing details apply.

Clear glass panels for observation purposes supplied.

BLAST equal to 500-lb. BOMB at 14 yds.

No damage whatsoever except slight pitting to front surface by glass envelope of bomb. The panel forced back the steel girders to which it was clamped at the back, the bottom girder having been pushed back 1" and the top girder 2".



BLAST equal to 500-lb. BOMB at 12 yds.

Panel completely dislodged resulting in several lenses being fractured by falling steel beams, etc. No glass dislodged from back face. Construction remained gas tight.

Photo shows typical cracking of lens.

(Courtesy J. A. King & Co., Ltd.)

FIG. 317. Blast test on Glascrete construction.

[Facing p. [illegible]]

2. "CERRUX" . . . Cellon Ltd., Kingston-on-Thames.

(In this case the self-adhesive film is supplied together with a varnish; the two together constituting the "Cerrux Process.")

3. "DUREX" . . . Durex Abrasives Ltd., Arden Road, Adderley Park, Birmingham 8.

4. "SELLOTAPE" . . . Adhesive Tapes Ltd., Brunel Road, Old Oak Common Lane, Acton, W.3.

5. "TRANSOTAPE" . . . Messrs. John Gosheron & Co., 1–6 Beech Lane, E.C.1

Self-adhesive film needs only to be pressed on the glass with a roller. As cellulose film is affected by moisture the treated panes should be given a waterproofing coat of varnish or lacquer.

(iii) *Cellulose Acetate Film.* The following materials have been approved :—

1. "BEXOID" . . . B.X. Plastics Ltd., Hale End, E.4.

2. "CLARIFOIL" . . . British Celanese Ltd., Celanese House, Hanover Square, W.1.

3. "DIALUX" . . . Dufay Chromex Ltd., Elstree, Herts.

4. "ERINOFORT" . . . Erinoid Ltd., Stroud, Gloucester.

5. "PHODOPHANE" . . . Messrs. May & Baker Ltd., 42–43 St. Paul's Churchyard, E.C.4.

(iv) *Cellulose Acetate Film Reinforced with Textile Netting.* The materials supplied by the following firms have been approved by the B.R.S. :—

1. CELLOFABRICS Ltd., 11 Gillingham Street, S.W.1.
2. Messrs. DOBSONS & M. BROWNE & Co. Ltd., DelBeta House, Nottingham.
3. DUFAY CHROMEX Ltd., Elstree, Herts.

Cellulose acetate film cannot be stuck to glass satisfactorily with ordinary gum or paste, but manufacturers can supply suitable adhesives or suggest recipes.

(v) *Self-adhesive Cellulose Acetate Film.* The film marketed by the following firm has been approved :—

DUREX ABRASIVES Ltd., Arden Road, Adderley Park, Birmingham 8.

(*d*) Strip Treatments

Suitable materials for strip application include :—

(i) The transparent cellulose and cellulose acetate films mentioned above.

(ii) Self-adhesive cloth tapes—pressing these on the glass with a warm iron helps them to stick better.

(iii) Any strong textile material stuck on the glass.

(iv) Metallic strip applied with a suitable adhesive.

One such which has been tested and approved by the B.R.S. is "Perma Led," supplied by :—

Perma Led Metal Co. Ltd., 41 King William Street, E.C.4.

(*e*) Liquid Coatings

Two approved materials are :—

1. "Arpco" . The Calico Printers' Association Ltd., St. James Buildings, Oxford Street, Manchester 1.
2. "Slick" . Slick Brands Ltd., Waddon, Croydon.

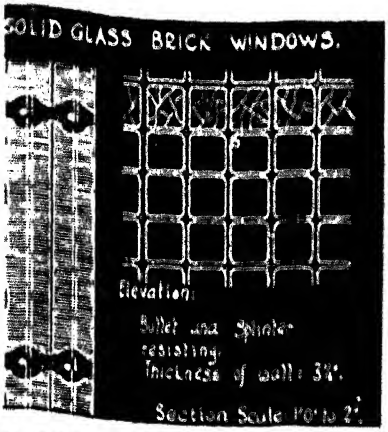
At least two good coats, in addition to any priming treatment recommended, should be applied. For large panes of glass, liquid treatments alone are not recommended.

Roof Glazing

In protecting roof glass, give special attention to retaining weather-proofness after fracture, and to precautions against injury to equipment by falling glass. Temporary weather protection is given by covering the glazing externally with a suitable hessian bitumen treatment. Support can be given by wire netting, which should be close up to the glass. To prevent all glass from falling some strong sheeting material must be securely suspended under the whole glazed area.

Glass Substitutes

Translucent materials possessing a light transmission approaching that of glass are at present difficult to obtain owing to the demands for aircraft production. Flexible cellulose acetate materials, reinforced with metal or fabric mesh are, however, obtainable. Alternatively oiled or waxed fabrics may be used. Suitable opaque materials, apart from boarding, are bituminous sheeting, felts, asbestos cement sheet and plaster boards.



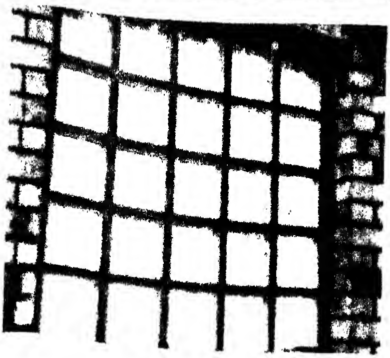
BLAST, BULLET AND SPLINTER RESISTING

Laminated Glass Brick Construction (Type BB BB).

Construction comprises two BB lenses specially laminated and doubly reinforced. Flemish pattern on both faces.

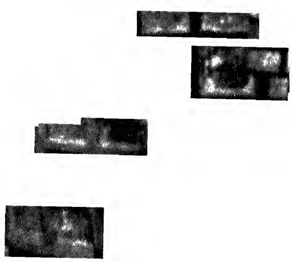
All lenses given sufficient insulation to absorb movement due to whip.

Clear glass panels for observation purposes supplied.



BLAST equal to 500-lb. BOMB at 14 yds.

No damage whatsoever except slight pitting to front surface by glass envelope of bomb. No signs of concrete cracking at back.



BLAST equal to 500-lb. BOMB at 12 yds.

Still no damage. Amount of pitting increased. Fine hair cracks in concrete at back. Panel forced back dislodging steel fixing beam.

(Courtesy J. A. King & Co. Ltd.)

FIG. 318.—Blast test on Glascrete construction.

[Facing p. 718.

Shop windows are prone to danger by blast because of their large areas. Within 200 ft. chance of survival is small.

The danger of flying glass is in no way eliminated by any bracing device. It is useful to provide a flexible setting for the glass. The following methods are available :—

1. Boarding up external display windows.
2. Bricking up the display space.
3. Improving panelling behind display spaces.
4. Wire netting.
5. Blinds and curtains.
6. Adhesive treatments.

Liquid coatings and paper strip are not recommended for plate glass.

Substitutes for Glass

Flexible substitutes may be either translucent or, where permanent obscuration is required, opaque. Most translucent substitutes are at present made of synthetic resins or cellulose substances reinforced with metal or textile mesh.

Alternatively cotton or linen textiles may be used ; these are not ordinarily windproof or rainproof, but may be obtained suitably treated with cellulose lacquer or with boiled linseed oil. Where permanent obscuration is required the following materials can be used :—

1. *Roof Glazing.* Galvanised flat sheet steel, composite sheets of asbestos and steel, hard wallboards, and flexible opaque materials such as combinations of wire mesh and bituminous sheeting.

2. *Vertical Glazing.* The materials described and in addition bituminous sheeting, plywood and plaster board can be used. Firm fixing is undesirable.

Glas-Crete*

Figs. 310–318 inclusive, reproduced by courtesy of J. A. King & Co. Ltd., illustrate incendiary, loading, impact and blast tests carried out on Glas-crete constructions developed by J. A. King & Co. Ltd., with Pilkington's glasses.

In the blast tests a 2 lb. glass-cased bomb providing a blast at 1 ft. equal to a 500 lb. bomb bursting at approximately

* *Figs.* 310–317 *between pp.* 712–713.

12 ft. was used. The bombs were hung from a wire rope in front of the centre of the panel at the appropriate distances. This was considered to be the most satisfactory arrangement to obtain the effects of pure blast perpendicular to the panels.

In view of the results obtained on the window constructions in the tests it was considered unnecessary to carry out blast tests on the roof light constructions. These types will carry the maximum *débris* load of 400 lb. per ft. super required by the Ministry of Home Security.

From these test results it will be seen that the radii of the vulnerable areas to pure blast from a 500 lb. H.E. bomb *in the open* are reduced from 300 yds. for ordinary unprotected glazing to the following :—

			Fig. No.
80 yds. radius .	Type	222 using wired glass.	313
40 ,, .	,,	600/300 using wired glass.	314
40 ,, .	,,	1212 using wired glass.	315
40 ,, .	,,	222 using armour plate glass.	313
24 ,, .	,,	600/300 using armour plate.	314
24 ,, .	,,	222 using pressed lens.	313
24 ,, .	,,	1212 using pressed lens.	315
24 ,, .	,,	1212 using armour plate.	315
16 ,, .	,,	88.	316
14 ,, .	,,	88 A.P.	317
12 ,, .	,,	88/88.	318

WAR DAMAGE REPAIR

When a building is bombed the local authority, acting under the Housing (Emergency Powers) Act, 1939,[178] and the Essential Buildings and Plant (Repair of War Damage) Act, 1939,[179] are empowered to enter in and repair war damage if they decide that the building is wanted for local housing or essential services.

Housing

The Housing Act states that the local authority can act where they are satisfied :

(*a*) That any building, whether a house or not, is in any respect unfit for housing purposes by reason of war damage ; and

(*b*) that the building is capable at reasonable expense of being rendered fit for housing purposes ; and

(*c*) that the lack of housing accommodation in the area of the authority makes it necessary that the building should be rendered so fit ; and

(*d*) that the person having control of the building is unable or unwilling to carry out the works necessary to render it so fit.

Procedure under the Act defined by Ministry of Health Circular 1810, issued in August, 1939, further clarified by Circular 2144, issued in September, 1940, involved the immediate execution of "first-aid" repairs, *e.g.*, "by placing a tarpaulin over the hole in a roof or by temporarily boarding up a hole in the wall." This can be done without any notice being served on the occupants or owners.

First-aid repairs "confine the repairs to the minimum necessary to make them reasonably fit as housing accommodation in war-time."

Essential Buildings other than Housing

The Essential Buildings and Plant (Repair of War Damage) Act, 1939,[179] gives similar powers to the local authority where they are satisfied :

(*a*) that any building used for purposes which . . . are essential to the welfare of the civil population has become wholly or partly incapable of use for those purposes by reason of war damage ; and

(*b*) that the buildings can be rendered fit . . . at reasonable cost ; and

(*c*) that lack of buildings available for the said purposes makes it essential that the building should be rendered so fit.

In this Act, explained in Circular 1848, issued in September, 1939, buildings are listed under the headings of the "appropriate Government departments," whose responsibility it is to decide whether the buildings are "essential," *e.g.*, bakeries, under the Ministry of Food, hospitals under the Ministry of Health, etc. "Generally speaking, the object of the Government is to ensure that the necessary funds for the repairs of

such buildings will be available both for local authorities and private owners, but there will be a distinction in that, while in some cases it will be the duty of the local authority to carry out repairs to certain classes of buildings, in the case of the ordinary private owner loans will only be available if he is willing but unable, without financial assistance, to carry out the necessary work."

Compensation for War Damage

Compensation is of first concern to private building owners. An Assessment Committee reviewing the question of damage assessment recommended that, except in the case of buildings such as churches, hospitals, etc., which have no ascertainable market value, damage "to immovable property should be assessed at *whichever is the less*

(*a*) the cost of reasonable reinstatement estimated by reference to the level of building costs prevailing in March, 1934, credit being taken for the old materials; or

(*b*) the diminution in market value, *i.e.*, the difference between the market value of the property in its condition immediately before the damage occurred and its market value in its damaged condition, the value in each case to be calculated on the basis of the market values prevailing in March, 1939, assuming the property to be freehold in possession and free from encumbrances and from any burden, charge or restriction other than rates and taxes."

When a House has been Bombed, but is still Habitable

The owner should notify the local council, who will undertake "first aid" repairs to the extent of making the house weatherproof and watertight. The cost of these repairs becomes a charge on the property to be deducted from any sum the owner may be awarded as compensation.

This compensation will be paid at the end of the war, but the amount will depend on what funds are then available for the purpose.

The repairs will be confined to essentials and will not include redecoration. A tenant remains responsible for the payment

of rent as long as the house is fit to live in, and rates must be paid while the house is occupied.

When Damage by Bombing is so Severe that the House becomes Uninhabitable

The position in regard to repairs is the same. To escape payment, a tenant should serve on the landlord a notice disclaiming the lease.

When a House is Damaged beyond Repair

The owner can do nothing beyond arranging for the district valuer to assess his claim. A tenant is entitled to disclaim the lease.

When a House is Owned on Mortgage

The owner on mortgage is in the same position in regard to repairs as if he owned the property outright. Even if his house is destroyed the mortgagor is still responsible in law for the mortgage repayments and the interest on the mortgage, but under the Emergency Power Act he can obtain relief from mortgage repayments. The Act provides for the postponement of payments, but does not relieve the owner on mortgage of eventual responsibility.

When the Tenant has a Repairing Lease

Provision has been made to relieve the tenant of liability to make good air raid damage. Relief from liability to pay rent does not apply to the case where a time bomb has compelled the tenant to evacuate premises temporarily. Shops where windows have been broken, plaster dislodged and fittings damaged by a bomb are not held to be unfit for business within the meaning of the Landlord and Tenant (War Damage) Act.

V.O.W. 1

When a building is damaged the owner or his representative must submit claim form V.O.W.1 within thirty days to the District Valuer. The form can be obtained from the local authority.

V.O.W.1 is the bare statement of claim. The form will be submitted by the District Valuer to his local valuations panel

consisting of professional men who are empowered to judge the merit of each claim, to raise it if necessary or to reduce it. Full bills of quantities or an elaborate schedule will seldom be necessary. First-aid repairs carried out by the owner should be added to the claim on V.O.W.1. Professional fees, properly incurred, for the preparation of plans and quantities and for superintendence of the work should be included in the " costs of reinstatement " and are payable at once without waiting for receipt of compensation at the end of the war.

Putting the Work in Hand

Once V.O.W.1 has been submitted the owner has done all he can do to claim compensation. He need not wait until his claim has been accepted before starting repairs. If his building is regarded as essential the local authority will start work, but civil building of all sorts costing more than £500 is controlled by the licensing system.

Materials

The fullest possible use of salvaged materials is recommended and the use of standard temporary coverings : " roofing felt, waterproof building paper, asbestos sheeting should be regarded as the normal method of repair."

FIRST AID REPAIRS

Policy

The official policy is summarised in the opening remarks in the section on War Damage Repair earlier in this chapter, but private owners of business premises and buildings used for human habitation are reminded that delay in first air repairs merely tends to increase the damage owing to rain, snow and frost, apart from the fact that the contents of buildings are liable to serious damage by exposure to the weather in a building partially damaged through air raids.

Repairs to the least damaged houses have already been carried out by municipalities and private owners. Speed is essential so as not to overload rest centres already full due to vacation of areas on account of time bombs and dispossession of premises damaged beyond repair.

Subject only to the prior claims of rescue, the sequence of

operations in first aid repairs should be firstly to deal with the safety of the premises and secondly to deal with the comfort of occupants.

In order to ensure safety in partially damaged premises demolition of unsafe sections may be necessary and the decision of an expert on the spot is often needed in a number of cases. Whilst a partially demolished wall may be useless in the case of any particular building, it may function quite satisfactorily as a buttress to the adjoining premises and care should be taken in demolishing such walls as expensive shoring of other kinds, might thereby be found necessary.

Next in order of importance would come the repair, stopping off or isolation of the several services to the damaged building. A gas installation should be turned off at the main and thoroughly tested before service is again turned on as the danger of fire through escape of gas would, of course, be a very real one. The same remarks apply to the electricity installation, and although the danger of leaking water is not quite so severe the damage it could cause would be sufficient to justify the closest attention to the whole installation before the water is again turned on.

Having attended to the measures required for the safety of the structure the considerations of comfort for the occupants will then need attention. There is no doubt that priority must be given to rendering the structure weatherproof, and subject only to the requirements of safety the roof should first be attended to and then blown-in windows and doors.

It will be quite evident that work of this nature cannot be dealt with by the building industry in accordance with the normally accepted methods of rendering lump sum figures or pricing up bills of quantities against a prepared specification, and the method adopted by local authorities is to appoint listed local contractors on a prime cost basis or for individual owners to employ private contractors in a similar way.

Materials and Methods

Roofs. Wherever possible it would be desirable for roof repairs to be carried out with materials which will effect a permanent repair, as the cost of ladders, scaffolding, etc., especially when procured and erected in war-time, would make

an interim temporary repair an inordinately expensive procedure. Tarpaulins may, of course, prove of considerable use in temporary roof repairs protecting valuable contents of buildings in exceptionally inclement weather. On the other hand, if left in position for any length of time they are liable to be dangerous in high winds and easily dislodge further partly damaged sections of the structure.

In industrial buildings roofing felt may be used with success provided this is two or three-ply, reinforced to deal with internal wind pressure which is likely to occur in structures of this kind temporarily repaired. It will, of course, be necessary in installing felt roofs to consider proper arrangements for side and end laps in order to give the requisite weathering and also to make a thorough examination of the battens and rafters upon which the felt is fixed. In the case of damaged tiles to the roofs it is desirable always to refix the original tiles if possible in order to make the repairs reasonably permanent. On the other hand, there have been many cases of successive damage to roofs and in the case of roofs covered with hand-made tiles laid on battens without any lining thereto the construction is particularly vulnerable to damage by blast pressure and tiles may be fixed and refixed time and time again when subjected to repeated damage by blast.

When roofs timbers are badly burnt or damaged by blast or splinters it will be necessary to replace them before the roof is repaired with tiles or slates, and this introduces considerable difficulties owing to the shortage of timber of any scantlings. There is no doubt that a roof once damaged by blast is very difficult to make reasonably sound and free from draughts.

With the object of meeting these difficulties, the author has evolved a new type of roof material which is rendered non-inflammable in manufacture, is flexible and has a high degree of thermal insulation with a view to the conservation of the heat as well as the provision of protection against the weather.

Brief particulars of this flexible roof material are given below :—

Flexitherm Material $\frac{5}{8}$ in. thick.

Weight	1 lb. per sq. ft.
Tensile strength	4,000 lb. per ft. width.
Safe unsupported span on roofs .	20 ft.

Overall thermal transmission . 0·4 B.Th.U. per sq. ft. per hr. per deg. Fah.

(Still air inside. 15 m.p.h. wind exposure outside.)

Equivalent to bituminous roofing on 7 in. concrete roof slab or 12 in. concrete walls.

Sizes available normally 20 ft. by 3 ft., but any size and thickness can be made up.

Non-inflammable, weatherproof, flexible, durable and camouflaged.

This is obtainable from Messrs. Wallington, Weston & Co. Ltd., St. John's Mills, Frome, Somerset.

Illustration A, Fig. 319, shows the use of the material in the repair of damaged cottages, in which the whole of the roof timbers have been either burnt out or otherwise destroyed. It will be seen that the material, which is suitable for unsupported spans up to a length of 20 ft., is ideal for this purpose as it can be fixed with no support between eaves and ridge, this latter being provided by a steel joist, timber or a reinforced concrete beam.

In the case of large spans in war buildings—workshops, aircraft assembly areas, hangars, etc.—the roofing material can be supported on a suspension bridge type of structure in which the steel required per square foot of floor space is reduced to the very minimum for structures of comparable span.

Illustration D_1 shows the combination of the author's pre-cast reinforced concrete three-pinned portal frame construction with the suspended roofing material which spans from the eaves beam E_1 to the ridge beam F_1. The provisions for the weathering are clearly shown on the enlarged details, the side seams being finished as shown in detail H_1.

When fixed in the ways indicated, the material provides complete weather resistance with a very high degree of thermal insulation as well as flexibility, which is so important a property when blast pressures have to be dealt with.

As already pointed out, rigid roofing materials are easily fractured and shattered by blast pressure, whereas flexible materials which yield to pressures from blast are able to survive much longer in aerial bombardment. The whole of the upper surface in use is rendered quite imperforate, but any holes caused by splinters can easily be filled in with Flexitherm

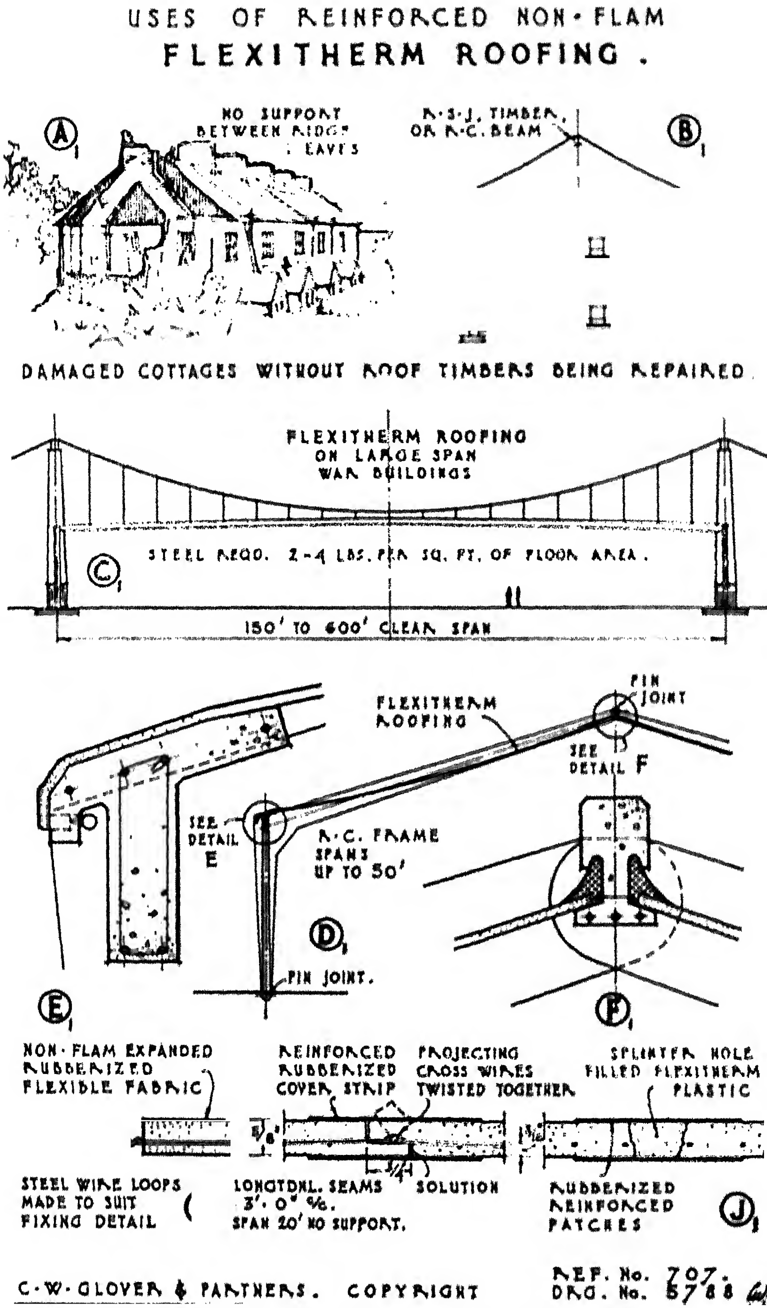


FIG. 319.—Details of and uses for flexible roofing material capable of spanning 20 ft. gap and having high thermal insulation.

plastic on an underpatch as shown in detail J_1, the surface being finished with a thin rubberised reinforced patch on the top.

In war conditions, owing to the scarcity of structural steel, the amount used in building construction has often a

Table CXXX

War-time Structures. Made to Comply with the Recommendations on Pp. 721 *et seq.*

Fig.	Type.	Remarks.	Span in feet.	Height to eaves. ft.	Lb. of steel per square foot of floor.	Cost per square foot of floor.	Page No.
273	A	Steel-framed building with 6″ concrete floor, 14″ brick walls and cor. iron roofing.	20	10	5·1	11/-	594
,,	B	,, ,, ,, ,,	40–60	10	5·0	8/-	594
,,	C	,, ,, ,, ,,	15–60	10	5·2	8/2	594
,,	D	,, ,, ,, ,,	40–60	10	5·3	8/2	594
,,	E	,, ,, ,, ,,	40–60	10	5·4	8/1	594
,,	F	,, ,, ,, ,,	15–60	10	5·0	8/1	594
,,	G	,, ,, ,, ,,	40–60	10	5·5	8/3	594
,,	H	,, ,, ,, ,,	25–60	10	5·5	8/3	594
,,	J	,, ,, ,, ,,	15–60	10	5·2	8/2	594
,,	K	,, ,, ,, ,,	25	10	6·0	12/-	594
,,	L	,, ,, ,, ,,	35	10	6·2	12/-	594
,,	M	,, ,, ,, ,,	100	10	8·0	13/-	594
,,	N	,, ,, ,, ,,	40–70	10	7·0	8/-	594
,,	O	,, ,, ,, ,,	80	10	7·5	7/10	594
,,	P	,, ,, ,, ,,	120	10	8·2	12/9	594
,,	Q	,, ,, ,, ,,(part boarded flat) . . .	30–80	10	9·0	15/-	594
274	R	R.C. frame, slab roof, 14″ walls	70	10	5·0	15/6	595
,,	S	,, ,, ,, ,,	15	10	4·5	12/9	595
,,	T	,, ,, ,, ,,	70	10	4·8	12/10	595
,,	U	,, sheeted R. 14″ walls	20	10	4·9	11/-	595
,,	V	,, slab R. 14″ walls .	15 & 60	10	4·5	10/6	595
,,	W	,, sheeted R. 14″ walls	20	10	4·0	13/-	595
,,	X	,, ,, ,, ,,	60	10	3·0	10/-	595
,,	Y	,, ,, ,, ,,	40	10	3·2	11/6	595
,,	Z	,, slab R. 14″ walls .	20	10	4·5	12/-	595
269	—	Class 5 protection . .	30	10	15·0	£1/-/-	585
319	C_1	Suspension	150	10	4·0	10/-	724
319	C_1	,, ...	600	10	2·5	9/-	724
319	D_1	3-pin arch with suspension roofing	50	10	1·0	5/6	724
320	—	3-pin arch with ordinary roofing	32	10	1·13	6/-	728

Note. In the above table reinforcement required for supports is included in the figures given.

Costs are estimated *on a uniform* basis as at March, 1941.

dominating influence upon the selection of the type of building erected.

Table CXXX, p. 725, summarises the steel required in the various designs illustrated in this work and emphasises the economies in steel to be effected by the adoption of the design indicated on illustration D_1, Fig. 319, p. 724.

Figs. 320 and 321 indicate details of the author's pre-cast reinforced concrete three-pinned arch construction, which has shown considerable economies in steel, cost and time of construction of war-time buildings (see Table CXXX, p. 725).

Windows. In first aid repair to windows, replacement of frames or the improvisation which is possible with salvaged timber, due regard should be paid to the weathering of the structure, and wherever possible the recesses in the walls should be utilised properly to provide this. The placing of felt over the frames on the outside keeps out the weather and by this means most buildings are maintained in a habitable condition while the electric light services are working.

The heat insulation of felt is, however, low, and the construction is draughty, resulting in many complaints of the cold. Reinforced cellulose acetate is ideal as a first aid material for windows and is not so subject to damage by blast and permits of the transmission of daylight.

Whilst the permanent reduction in the area of illumination through windows is not recommended, it may be remembered that sufficient daylight may be admitted through about half the normal window area provided this half is at the upper portion of the opening. A square foot of window area near the ceiling is very much more effective than the same area lower down.

Internal Partitions. Internal partitioning is most easily repaired by means of studding and felt. Bituminous insulation board is difficult to obtain, as are most of the fibre boards of the insulating or of the hard board variety. Holes made by small splinters can easily be patched over and the decorations made good, deferring more substantial repairs until a more propitious moment.

External Walls. The obliteration of splinter marks on the exteriors of buildings except in the case of those of a monumental nature or of national importance is deprecated and is

a needless waste of material. On the other hand, perforations due to splinters can best be made good by means of cement and sand, deferring any further treatments until the permanent repairs are undertaken. Such walls after repair can be protected against the weather by means of roofing felt spiked on with protective battens as necessary, but this will only be found of importance in the case of very exposed sites.

NOTES ON SINGLE-STOREY WARTIME FACTORY DESIGN

Generally

Intelligent development of design methods in the light of recent bombing experience can do much to minimise damage under aerial bombardment.

The dangers are, in order of severity :—

Fire by incendiary bomb.
Brisance due to direct hit.
Blast pressures from near miss.
Splinters from local H.E. bomb burst.
Earth tremor from bomb impact.
Settlement due to cratering at near miss.

War experience in this country has shown that far more steel frame buildings are destroyed or damaged by fire than by any other bombing effects. The obvious precaution is to utilise fire-resisting materials wherever possible and to limit the combustible materials used to the essential minimum.

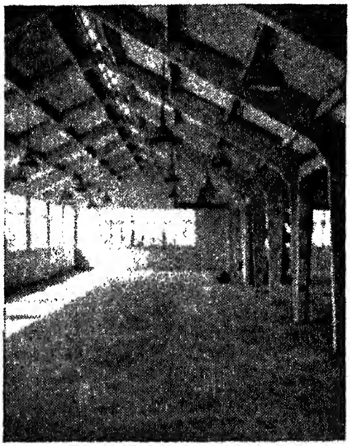
Decentralisation by planning small isolated buildings is at all times preferable to the erstwhile tendency to large centralised establishments. Experience has shown that in the event of a direct hit on any part of a large single-storey factory building, all the roofing, sheeting and windows are destroyed.

The advantage of division of the factory into separate groups of buildings each containing small production units will therefore be apparent.

Framing

As already pointed out, load bearing walls are a source of danger and loads should therefore be carried on framework to the foundations. In the design of any framework, consideration should be given to the possible effects of displacement of

FACTORY EXTENSION AT UPTON 1940



THIRTY · FIFTH DAY 21·6·40

COPYRIGHT
PATENT APPLIED FOR
REF. 12544/40

BUILDING · 121′ × 50′
TOTAL TIME · 5 WEEKS
INCLUDING MANUFACTURE OF MOULDS, CASTING OF UNITS, ERECTION, LIGHTING & HEATING, DECORATING & BLACKOUT

WAR OFFICE APPROVAL Nº
JKT/798/G.G (F.W.1c) 8·7·40

ALL-IN COST · 5/10
PER SQ.FT. OF FLOOR SURFACE.

AVERAGE Nº OF MEN EMPLOYED
22

COMMENCED 17·5·40
FINISHED 21·6·40

MAXIMUM Nº OF MEN EMPLOYED
35

ON A BUILDING OF 49,500 SQ.FT A SAVING OF £7,890, 200 TONS OF STEEL AND 5 MONTHS IN CONSTRUCTION TIME IS SHOWN AGAINST A STEEL FRAMED BUILDING OF THE SAME SIZE

SEE PLAN Nº 5706
STEEL REQUIRED 1·13 LB. PER SQ.FT.

C.W.GLOVER & PARTNERS
CONSULTING ENGINEERS AND ARCHITECTS

Fig. 320.—Fire-resisting wartime building designed to meet the shortage of timber and steel.

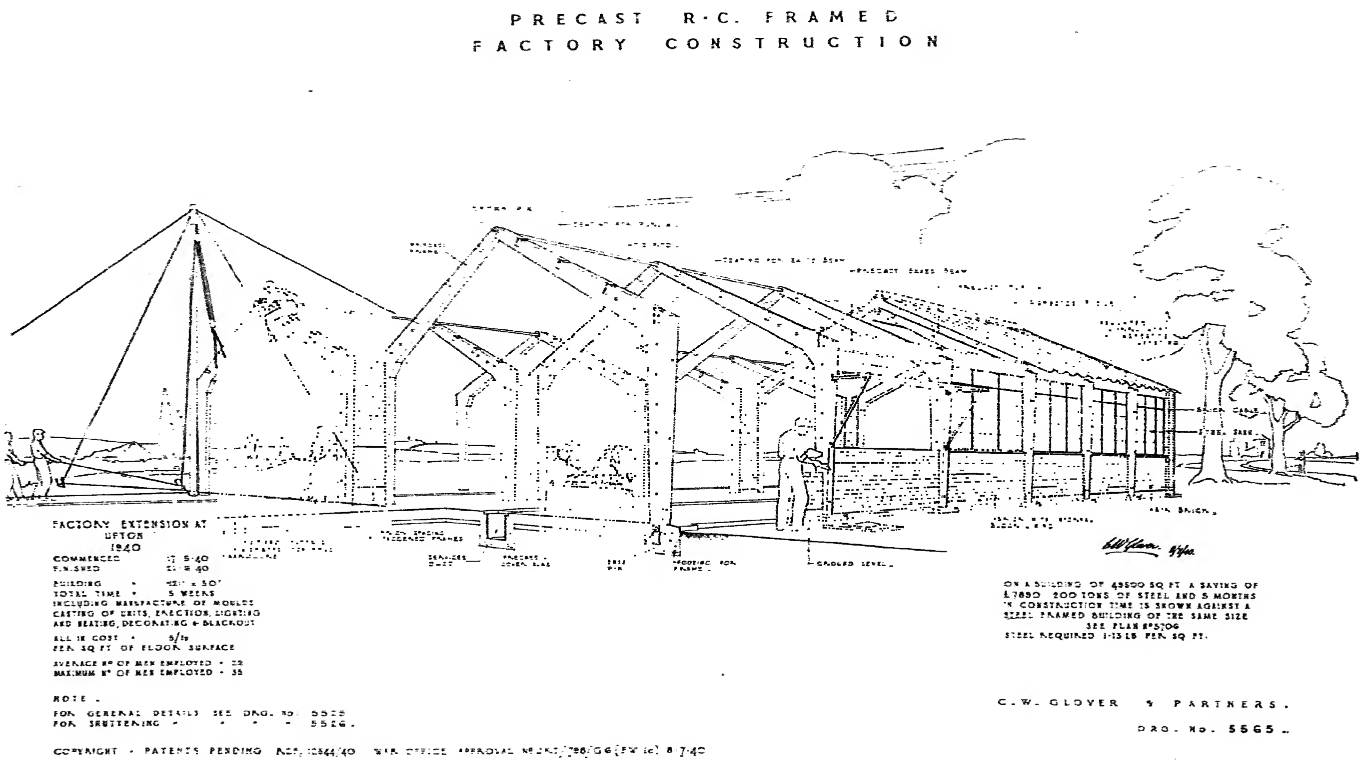


FIG. 321.—Illustrating method of constructing pre-cast reinforced concrete, 3-pin portal frames for buildings illustrated in Figs. 320 and 322. Spans up to 60 ft. economically possible.

foundations or partial damage to the frame, and joints between members in steel or reinforced concrete should therefore be designed to permit of this movement without introducing progressive destruction to other sections of the structure. Provision for this movement is easier in steel-framed buildings than in the case of the normal type of reinforced concrete-framed design in which monolithic continuity is a *sine qua non*.

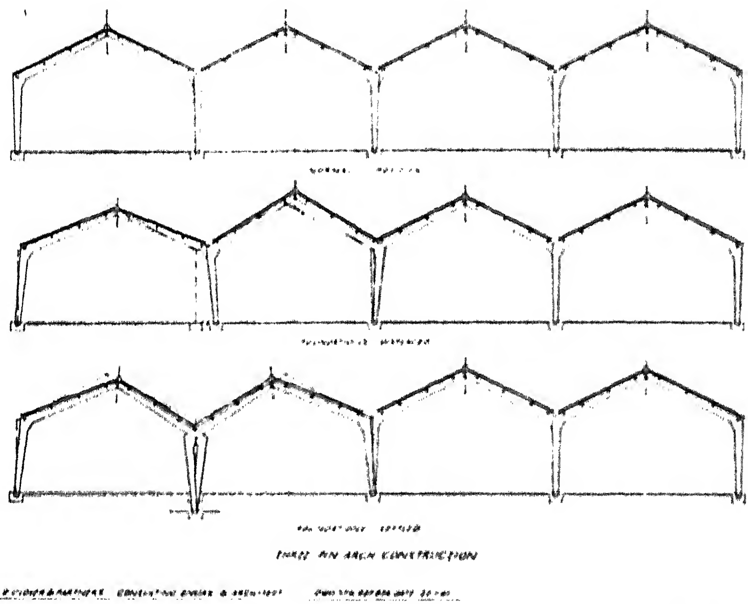


FIG. 322.—Showing adaptability of 3-pinned portal frames to movement of foundations without loss of structural stability or the development of dangerous stresses.

With the author's special reinforced concrete design shown in Figs. 320 and 321 and in which the three pinned arch portal frame is utilised, considerable displacement of any individual foundation may take place without overstressing any other sections of the structure (see Fig. 322).

The whole of the units pre-cast in vibrated aluminous cement and reinforced with plain bars are connected on site in such a way as to permit of the complete removal of any of the units without causing progressive failure to the rest of the structure.

It will also be seen from Fig. 320 that phenomenal economies in steel, cost and construction time are possible by this method.

In steel-framed buildings also the sudden removal of one member should not bring about the collapse of the remainder.

The chief risk to roof steelwork is the sudden shearing of the stanchion cap connection, which in war-time structures should consequently be made stronger and wider than is normal. If the stanchion spacing is no more than 30 ft. in either direction and the steelwork passing over supports be made continuous, the complete removal of one stanchion would not as a rule result in the fall of the roof girder work which is usually at such a point relieved of its sheeting load, the covering having been blown off.

Roofs

Explosions inside factories tend to blow the roofs upwards, and the following precautions should therefore be taken :—

1. In the design of the framework provide for upward lift equal to the aggregate breaking load on the fixing bolts for the sheeting. (Note. The limitation of fixing bolts, to one to every 8 sq. ft. of sheeting, usually ensures the break away of the sheeting without imposing excessive upward lifts on purlins and trusses.)

2. The temporarily lifted roof load may be suddenly applied in the downward direction after the explosion if the sheeting holds, and this, combined with suction effects, may cause stresses well up to the elastic limit of the material.

3. The use of angles in lieu of flats for ties results in added stiffness and is always to be recommended.

4. The liberal use of wind bracing (at least twice the normal amount) will do much to minimise the danger of spreading collapse.

In the case of flat roofs designed to give the specified overhead protection against shell fragments and small incendiary bombs—such as by a 4-in. reinforced concrete slab—these should be designed for and anchored against an internal blast pressure equivalent to at least an upward lift of 100 lb. per square foot.

Walls

External walls of war-time factory buildings should be self-standing and imperforate to a height of 7 ft. constructed of materials and to the appropriate thicknesses required for splinter protection (see Table X, p. 38). The walls should not be bonded to the casings of the stanchions supporting roof steelwork so as to permit of their yielding to blast pressure without transmitting excessive lateral pressures on the framing. It is advisable that the space between the top of the walls and the eaves of the building should be filled with some brittle material which would blow harmlessly on to some anti-scatter protection consisting of large-mesh netting fixed to the steel framing behind the sheeting.

Corrugated iron external sheeting to walls of framed buildings is not recommended for the reason that it transmits to the framing the full force of blast pressure from bombs bursting near the buildings.

Internal partitions should be avoided if possible, but can safely be made of open wire netting or fibre board which would not shatter under the effects of blast pressure. Asbestos cement, glass or other brittle materials should be studiously avoided in war-time structures used for human occupation.

In large buildings substantial internal partitions constructed to the thicknesses required for splinter protection are a considerable advantage as they serve to localise the effects of direct hits.

Roof Coverings

Coverings of an unyielding brittle nature should be carefully avoided, but in cases where purlins are provided with the framework, corrugated iron, R.P.M. or Durasteel provide ideal sheeting materials. They withstand blast pressure from external near misses to a much greater extent than asbestos cement roofings ; they can be perforated with splinters without shattering and blow off completely without imposing undue stresses on the framework when subjected to pressure by blast from a bomb bursting within the building.

In fixing insulating linings, these should on no account be placed under the purlins, as when so fixed the linings would impart a dangerously excessive upward lift to the roof purlins

and framework when subjected to internal blast pressure. Some form of reinforced flexible and insulating roof covering such as Flexitherm, described on p. 722, is ideal for war-time structures.

Owing to the danger of shattered glass, war-time factories should preferably be designed with the minimum of window and roof lighting which should be provided by a reinforced flexible glass substitute.

Services

In installing services in war-time factories careful consideration must be given to accessibility for repair and protection against bomb damage. In providing the latter it is not sufficient to bury services deep in the ground, as earth movements may often cause serious breaks. A central trench for services down each bay together with ring mains giving alternate service routes are probably the best arrangements. The trenches must be protected with the head cover specified in the code (see p. 525) and mains supported freely with long suspenders on wall brackets so as to permit movement of the trench without rupture of the mains.

Animals (see also pp. 536–548)

The protection of the animal population, which aggregates over 100 millions in this country, is of paramount importance in war-time.

Milch cows must be protected in order that the supply of milk, vital to the welfare of the population, be maintained; livestock for the meat market; and horses for draught (so much more necessary in the days of petrol rationing) are essential to the preservation of this country in war.

The public itself must be protected from the danger of injured and frenzied animals rushing about in air raids.

The principal animal welfare societies, including the undermentioned, have amalgamated their activities under the Ministry of Home Security and are operating as the National Air Raids Precaution Animals Committee :—

The National Veterinary Medical Association.
The Royal Society for the Prevention of Cruelty to Animals

The People's Dispensary for Sick Animals.

Our Dumb Friends League.

Scottish Society for the Prevention of Cruelty to Animals.

National Canine Defence League.

West of Scotland Society for the Prevention of Cruelty to Animals.

A large voluntary organisation of Animal Guards has been recruited and a census of the animal population has been made.

Identity discs have been distributed and affixed to all animals which might get lost in air raids.

Animal first-aid posts have been set up throughout the country and fleets of mobile units equipped for first-aid and with special conveyances for injured animals have been created.

Many dogs and cats were needlessly destroyed on the outbreak of war by mistaken owners ignorant of protective precautions, and one serious consequence has been the alarming increase of rats and mice, which may endanger the nation's food supplies.

The reader interested in this subject is urged to procure the N.A.R.P.A.C. handbook, which deals with the care of animals and includes recommendations for substitute foods and war diets.

Tested gas-proof shelters for dogs, cats and pets are now available for kennel or home use. The shelter consists essentially of a strong but light gas-tight kennel-like box, of such dimensions that it can be used in a living room. It has a flat front, having a gas-proof washer fixed all round.

The door consists of a wooden frame, carrying a strong celluloid window; the outlet valve is on the top. At the back of the shelter is a bellows arrangement fitted with a special gas filter.

When the dog is in the shelter and the door closed, there is sufficient fresh air in the shelter to last a considerable time without working the bellows. The areas of the medium and large shelters have been calculated in each case to ensure that with proper operation of the bellows the content at no time exceeds 0·167 per cent. CO_2.

The standard size kennel is suitable for any breed of dog up

to cocker spaniel. The large size kennel is for larger breeds up to Airedale size.

Standard size . .	19″ wide,	17″ high,	2′ 6″ deep.
Large size . .	24″ ,,	21″ ,,	3′ 0″ ,,

Available from Army and Navy Stores.

The author has endeavoured to present in a concise form authoritative information upon the structural precautions required in Civil Defence, and has consulted all the records of test results available at the time of going to press.

In addition to describing *what* should be done in defensive measures he has endeavoured to indicate *how* it could be done.

If he is thus able to contribute, successfully, a humble part in the protection of the defenceless citizen his efforts will be well rewarded.

APPENDIX I

"Our most valuable weapon against gas is knowledge of the facts about gas" [81].

SUMMARISED PARTICULARS OF WAR GASES

Common name of agent: ADAMSITE (D.M.) (Diphenylamine-chlorarsine).*
Chemical symbol: $(C_6H_4)_2$ NHAsCl.
Classification: Sternutator harassing agent.
Persistency—
  Winter: Ten minutes in open from candles.
  Summer: Ten minutes in open from candles.
Irritant concentration, ten minutes exposure: 0·00038 oz. per 1,000 cub. ft.
Intolerable concentration, three minutes exposure: 0·005 oz. per 1,000 cub. ft.
Lethal concentration, three minutes exposure: 3·0 oz. per 1,000 cub. ft.
Melting-point: 387° F. Boiling-point: 770° F. Decomposes below boiling-point.
Volatility: Negligible.
Vapour pressure: Negligible.
Vapour density compared with that of air: No vapour, disseminated as solid.
Specific gravity of solid agent at 68° F.: 1·65.
Stability: Stable in steel containers.
Solvents: Furfural acetone.
Action on metals: Very slight.
Action with water: Insoluble. Hydrolyses with difficulty.
Product of hydrolysis: HCl D.M. oxide $[(C_6H_4)_2NHAs]_2O$. D.M. oxide very toxic if swallowed.
Odour: No pronounced odour.
Odoriferous concentration: 0·0025 oz. per 1,000 cub. ft.
Physiological effect: Headache, nausea, violent sneezing, followed by temporary physical debility.
Protection required: Best type of filter in gas mask canister.
Neutralisation: Gaseous chlorine bleach liquor.
First aid: Breathe low concentrations of chlorine from bleaching-powder bottle.
Uses: Candle; destroyer smoke attack; burning type air bombs.

Notes. A bright yellow, crystalline solid.
Respirator affords complete protection.

* Starting with arsine AsH_3 and ammonia NH_3, substitution of three chlorine atoms (Cl) for three hydrogen atoms (H) in the former and two phenyl groups (C_6H_5) for two hydrogen atoms in the latter gives the compounds arsenic tri-chloride $AsCl_3$ and diphenylamine $(C_6H_5)_2NH$.
These react together with the elimination of two molecules of hydrogen chloride (HCl) to form Diphenylaminechlorarsine [81] $(C_6H_4)_2NHAsCl$.

Common name of agent : BROMACETONE.
Chemical symbol : (CH_3COCH_2Br).
Classification : Lacrimator—harassing.
Persistency—
Winter : Two days in open ; seven days in woods.
Summer : Three hours in open ; one to two hours in woods.
Irritant concentration, ten minutes exposure : 0·0015 oz. per 1,000 cub. ft.
Intolerable concentration, ten minutes exposure : 0·010 oz. per 1,000 cub. ft.
Lethal concentration, ten minutes exposure : 3·2 oz. per 1,000 cub. ft.
Melting-point : – 65° F. Boiling-point : 275° F.
Volatility : 75 oz. per 1,000 cub. ft. air at 68° F.
Vapour pressure : 9 mm. mercury at 68° F.
Vapour density compared with that of air : 4·7.
Specific gravity of solid agent at 68° F. : 1·60.
Stability : Unstable in heat and light.
Solvents : Fats and organic solvents.
Action on metals . Very corrosive to iron.
Action with water : None.
Product of hydrolysis : None.
Odour : Pungent and stifling.
Odoriferous concentration : 0·0005 oz. per 1,000 cub. ft.
Physiological effect : Vapour ; severe lacrimation ; liquid ; produces blisters, often toxic.
Protection required : Gas mask, absorbent only.
Neutralisation : Alkali.
First aid : Wash eyes boric acid. Wash skin warm sodium carbonate solution.
Uses : Projectiles and grenades.

Common name of agent : BROMO-BENZYL-CYANIDE (B.B.C.) (French : Camite).
Chemical symbol : ($C_6H_5CHBrCN$).
Classification : Lacrimator harassing and persistent tear gas.
Persistency—
Winter : Several weeks.
Summer : Three days in open ; seven days in woods.
Irritant concentration, ten minutes exposure : 0·00015 oz. per 1,000 cub. ft.
Intolerable concentration, ten minutes exposure : 0·0008 oz. per 1,000 cub. ft.
Lethal concentration, ten minutes exposure : 3·5 oz. per 1,000 cub. ft.
Melting-point : 77° F. Boiling-point : 467° F.
Volatility : 0·13 oz. per 1,000 cub. ft. air at 68° F.
Vapour pressure : 0·0112 mm. mercury at 68° F.
Vapour density compared with that of air : 6·6.
Specific gravity of solid agent at 68° F. : 1·47.
Stability : Slowly decomposes.
Solvents : Chlorbenzene, chloroform, phosgene and chloropicrin.
Action of metals : Very corrosive to iron ; lead or enamel-lined shells required.
Action with water : Slowly hydrolyses.
Product of hydrolysis : HBr and various compounds.
Odour : Like sour fruit. Irritates before odour can be detected.
Physiological effect : Severe lacrimation and nose irritation.
Protection required : Gas masks ; absorbents in canister only.
Neutralisation : Alcoholic sodium hydroxide spray.
First aid : Wash eyes with boric acid solution.
Uses : 75 mm. artillery shell or airplane spray.

Notes. A yellowish-brown crystalline solid when pure As used a liquid mixture. Invisible in gaseous state.
Respirator affords complete protection.

Common name of agent: CHLOR-ACETO-PHENONE (C.A.P.).
Chemical symbol: ($C_6H_5COCH_2Cl$).
Classification: Lacrimator—harassing tear gas.
Persistency—
Winter: Several weeks in solid; burning mixture, ten minutes.
Summer: Solid for days; burning mixture, ten minutes.
Irritant concentration, ten minutes exposure: 0·0003 oz. per 1,000 cub. ft.
Intolerable concentration, ten minutes exposure: 0·0045 oz. per 1,000 cub. ft.
Lethal concentration, ten minutes exposure: 0·85 oz. per 1,000 cub. ft.
Melting-point: 138° F. Boiling-point: 476° F.
Volatility: 0·106 oz. per 1,000 cub. ft. air at 68° F.
Vapour pressure: 0·013 mm. mercury at 68° F.
Vapour density compared with that of air: 5·2.
Specific gravity of solid agent at 68° F.: 1·30.
Stability: Stable.
Solvents: Chloroform, chloropicrin, ethylenedichloride, monochloracetone.
Action on metals: Tarnishes steel slightly.
Action with water: None.
Product of hydrolysis: Not readily hydrolysed.
Odour: In low concentrations like apple blossoms.
Odoriferous concentration: 0·0002 oz. per 1,000 cub. ft.
Physiological effect: Eye and skin irritation, copious flow of tears and spasm of eyelids.
Protection required: Gas masks; both absorbent and effective filter.
Neutralisation: Strong hot sodium carbonate solution.
First aid: Wash eyes boric acid. Wash skin warm sodium carbonate solution.
Uses: Candles and grenades as burning mixtures; grenades; artillery shell; airplane spray and bombs as solution.

Notes. A solid, almost invisible in gaseous state, recognised by irritation to eyes.

Respirator affords complete protection.

Common name of agent : CHLORINE.
Chemical symbol : (Cl_2).
Classification : Lung injurant—casualty agent.
Persistency—
  Winter : Ten minutes in open ; one hour in woods.
  Summer : Five minutes in open ; twenty minutes in woods.
Irritant concentration, ten minutes exposure : 0·029 oz. per 1,000 cub. ft.
Intolerable concentration, ten minutes exposure : 0·10 oz. per 1,000 cub. ft.
Lethal concentration, ten minutes exposure : 5·60 oz. per 1,000 cub. ft.
Melting-point : −152·5° F. Boiling point : −28·5° F.
Volatility : 19,369 oz. per 1,000 cub. ft. air at 68° F.
Vapour pressure : 4,993 mm. mercury at 68° F.
Vapour density compared with that of air : 2·5.
Specific gravity of solid agent at 68° F. : 1·46.
Stability : Stable in iron cylinders, if dry.
Solvents : Chloropicrin, phosgene, CCl_4.
Action on metals : None if dry ; vigorous corrosion if wet.
Action with water : A little dissolves forming HCl, HOCl and ClO_2.
Product of hydrolysis : HCl, HOCl, ClO_2.
Odour : Pungent smell of bleaching powder.
Odoriferous concentration : 0·01 oz. per 1,000 cub. ft.
Physiological effect : Burns upper respiratory tracts.
Protection required : Gas masks ; absorbents in canister only.
Neutralisation : Alkali, solution or solid.
First aid : Keep patient quiet and warm and treat for bronchial pneumonia.
Uses : Mixed with other gases in shells, bombs and cylinders.

Notes.—A greenish-colour gas ; is dissolved in water and will eventually rot clothing, highly lethal, non-persistent.
Respirator affords complete protection.

Common name of agent : CHLOROPICRIN (P.S.) (vomiting gas).
Chemical symbol : (Cl_3CNO_2).
Classification : Lung injurant, lacrimator—casualty, harassing agent.
Persistency—
Winter : Twelve hours in open ; one week in woods.
Summer : One hour in open ; four hours in woods.
Irritant concentration, ten minutes exposure : 0·009 oz. per 1,000 cub. ft.
Intolerable concentration, ten minutes exposure : 0·050 oz. per 1,000 cub. ft.
Lethal concentration, ten minutes exposure : 2·00 oz. per 1,000 cub. ft.
Melting-point : $-92{\cdot}4^\circ$ F. Boiling-point : 233° F.
Volatility : 165 oz. per 1,000 cub. ft. air at 68° F.
Vapour pressure : 18·3 mm. mercury at 68° F.
Vapour density compared with that of air : 5·6.
Specific gravity of solid agent at 68° F. : 1·66.
Stability : Stable for long periods in steel containers.
Solvents : Phosgene, chloroform, chlorine, CS_2, C_6H_6. C_2H_6OH.
Action on metals : Produces slight tarnish only.
Action with water : Very slightly soluble.
Product of hydrolysis : Hydrolyses with difficulty.
Odour : Sweetish, like fly-paper.
Odoriferous concentration : 0·0073 oz. per 1,000 cub. ft.
Physiological effect : Lacrimates, irritates nose and throat ; produces nausea and lung irritation in order as concentration increases and slight eye irritation.
Protection required : Gas masks with high grade absorbents in canisters.
Neutralisation : Sodium sulphite solution.
First aid : Wash eyes boric acid ; keep patient warm, protect throat from infection.
Uses : Mixed with other gases in shells and bombs, but used pure in spray form.

Notes. A colourless, volatile liquid with a pungent odour ; semi-persistent Respirators affords complete protection.

Common name of agent : CYANOGEN CHLORIDE.
Chemical symbol : (CNCl).
Classification : Systemic toxic casualty agent.
Persistency

Winter : Twenty minutes in open ; two hours in woods.
Summer : Ten minutes in open ; twenty minutes in woods.

Irritant concentration, ten minutes exposure : 0·0025 oz. per 1,000 cub. ft.
Intolerable concentration, ten minutes exposure : 0·005 oz. per 1,000 cub. ft.
Lethal concentration, ten minutes exposure : 0·40 oz. per 1,000 cub. ft.
Melting-point : 21° F. Boiling-point : 59° F.
Volatility : 3,300 oz. per 1,000 cub. ft. air at 68° F.
Vapour pressure : 1,000 mm. mercury at 68° F.
Vapour density compared with that of air : 1·98.
Specific gravity of solid agent at 68° F. : 1·22.
Solvents : Organic solvents.
Stability : Unstable ; stability increased when mixed with $AsCl_3$.
Action on metals : None if dry ; corrodes metals if wet.
Action with water : Slightly soluble.
Product of hydrolysis : HCl ; cyanuric acid.
Odour : faint.
Odoriferous concentration : 0·0025 oz. per 1,000 cub. ft.
Physiological effect : Irritates eyes and lungs.
Protection required : Gas mask ; absorbents only.
Neutralisation : None necessary.
First aid : Fresh air ; cold water in face ; artificial respiration.
Uses : Artillery shell.

Common name of agent: DI-PHENYL-CHLOR-ARSINE (D.A. (German: Clark I.)
Chemical symbol: $(C_6H_5)_2$ AsCl.
Classification: Sternutator - harassing.
Persistency—
Winter: Five minutes by H.E. detonation ten minutes by candle.
Summer: Five minutes by H.E. detonation ten minutes by candle.
Irritant concentration, ten minutes exposure: 0·0005 oz. per 1,000 cub. ft.
Intolerable concentration, ten minutes exposure: 0·0012 oz. per 1,000 cub. ft.
Lethal concentration, ten minutes exposure: 1·50 oz. per 1,000 cub. ft.
Melting-point: 102° F. Boiling-point: 700° F. approx.
Volatility: 0·00068 oz. per 1,000 cub. ft. air at 68° F.
Vapour pressure: 0·0005 mm. mercury at 68° F.
Vapour density compared with that of air: Practically no vapour, all solid particles.
Specific gravity of solid agent at 68° F.: 1·4.
Stability: Slowly decomposes.
Solvents: Acetone, chloroform, chloropicrin.
Action on metals: Vigorous corrosion on steel.
Action with water: Slowly hydrolyses.
Product of hydrolysis: HCl; Da Oxide (Da oxide is poisonous if swallowed).
Odour: Like shoe polish.
Odoriferous concentration: 0·0003 oz. per 1,000 cub. ft.
Physiological effect: Sneezing, vomiting, headache.
Protection required: Best type filter in gas mask canister.
Neutralisation: Caustic gaseous chlorine.
First aid: Chlorine in low concentrations.
Uses: Burning-type munitions.

Notes. A colourless, crystalline solid which when heated gives off an almost odourless smoke. Generally invisible except near source. Can still be effective although not visible.

Respirator affords complete protection.

Common name of agent : DI PHENYL-CYAN-ARSINE (D.C.)
(German : Clark II.)
Chemical symbol : $(C_6H_5)_2AsCN$.
Classification : Sternutator harassing.
Persistency—
Winter : Five minutes by H.E. detonation, ten minutes by candle.
Summer : Five minutes by H.E. detonation, ten minutes by candle.
Irritant concentration, ten minutes exposure : 0·0001 oz. per 1,000 cub. ft.
Intolerable concentration, ten minutes exposure ; 0·00025 oz. per 1,000 cub. ft.
Lethal concentration, ten minutes exposure : 1·0 oz. per 1,000 cub. ft.
Melting-point : 91° F. Boiling point : 660° F.
Volatility : 0·0015 oz. per 1,000 cub. ft. air at 68° F.
Vapour pressure : 0·0001 mm. mercury at 68° F.
Vapour density compared with that of air : 8·8.
Specific gravity of solid agent at 68° F. : 1·45.
Stability : Very stable.
Solvents : Chloroform.
Action on metals : Vigorous corrosion on iron and steel.
Action with water : None.
Product of hydrolysis : None.
Odour : Like garlic and bitter almonds.
Odoriferous concentration : 0·0003 oz. per 1,000 cub. ft.
Physiological effect : Sneezing, vomiting, headache.
Protection required : Gas masks with best type of filter.
Neutralisation : Caustic gaseous chlorine.
First aid : Chlorine in low concentrations.
Uses : Artillery shell.

Notes. A crystalline solid with properties similar to D.A.
Respirator affords complete protection.

Common name of agent: DI-PHOSGENE (German: Perstoff; French: Surpolite).
Chemical symbol: ($ClCOOCCl_3$).
Classification: Lung injurant—casualty agent.
Persistency—
Winter: Thirty minutes in open; three hours in woods.
Summer: Fifteen minutes in open; sixty minutes in woods.
Irritant concentration, ten minutes exposure: 0·005 oz. per 1,000 cub. ft.
Intolerable concentration, ten minutes exposure: 0·40 oz. per 1,000 cub. ft.
Lethal concentration, ten minutes exposure: 0·5 (U.S.), 0·05 (Germany) oz. per 1,000 cub. ft.
Melting-point: −70° F. Boiling-point: 260·6° F.
Volatility: 120 oz. per 1,000 cub. ft. air at 68° F.
Vapour pressure: 10·3 mm. mercury at 68° F.
Vapour density compared with that of air: 6·9.
Specific gravity of solid agent at 68° F.: 1·65.
Stability: Stable in dry steel containers.
Solvents: Phosgene, chloropicrin.
Action on metals: None if dry, corrosion if wet.
Action with water: Hydrolyses slowly.
Product of hydrolysis: $ClCO_2$; CO_2; HCl.
Odour: Disagreeable, suffocating.
Odoriferous concentration; 0·0088 oz. per 1,000 cub. ft.
Physiological effect: Burns lower lung surfaces, causing œdema.
Protection required: Gas masks; absorbents in canister only.
Neutralisation: Steam hydrolyses alkalies and amines react with C.G.
First aid: Keep patient quiet; administer heart stimulants, give oxygen in severe cases; treat like pleurisy.
Uses: Shells and cylinders.

Notes. A colourless liquid, invisible in the gaseous state, non-persistent, highly lethal.
Respirator affords complete protection.

Common name of agent : ETHYL-DI-CHLOR-ARSINE (German : Dick).
Chemical symbol : $C_2H_5AsCl_2$.
Classification : Lung injurant, sternutator, vesicant casualty, harassing agent.
Persistency —
Winter : Two to four hours in open ; twelve hours in woods.
Summer : One to two hours in open ; two to six hours in woods.
Irritant concentration, ten minutes exposure : 0·001 oz. per 1,000 cub. ft. (causes sneezing).
Intolerable concentration, ten minutes exposure : 0·01 oz. per 1,000 cub. ft.
Lethal concentration, ten minutes exposure : 0·50 oz. per 1,000 cub. ft.
Melting point : − 22° F. Boiling-point : 312° F.
Volatility : 100 oz. per 1,000 cub. ft. air at 68° F.
Vapour pressure : 5·0 mm. mercury at 68° F.
Vapour density compared with that of air : 6·5.
Specific gravity of solid agent at 68° F. : 1·70.
Stability : Stable.
Solvents : Ethyl chloride.
Action on metals : None.
Action with water : Hydrolyses slowly.
Product of hydrolysis : Ethylarseneous oxide and HCl (hydrolysis product is poisonous if swallowed).
Odour : Biting irritant.
Odoriferous concentration : 0·0010 oz. per 1,000 cub. ft.
Physiological effect : Vesicant, one-sixth as powerful as mustard. Powerful sternutator ; causes paralysis of the fingers.
Protection required : Gas masks and protective clothing.
Neutralisation : Sodium hydroxide solution.
First aid : Wash skin with warm sodium carbonate solution
Uses : Artillery shell ; airplane spray.

Common name of agent : ETHYL-IODO-ACETATE (K.S.K.).
Chemical symbol : CH_2I, CO, OC_2H_5.
Classification : Persistent tear gas—harassing agent.
Persistency—
  Winter.....................................
  Summer ....
Irritant concentration, ten minutes exposure : . .... oz. per 1,000 cub. ft.
Intolerable concentration, ten minutes exposure : .... oz. per 1,000 cub. ft.
Lethal concentration, ten minutes exposure : .... oz. per 1,000 cub. ft.
Melting-point : − 16° F. Boiling-point : 356° F.
Volatility : .... oz. per 1,000 cub. ft. air at 68° F.
Vapour pressure : ...... mm. mercury at 68° F.
Vapour density compared with that of air :......................
Specific gravity of solid agent at 68° F. :.........................
Stability : Stable.
Action on metals : Slight.
Action with water : None.
Product of hydrolysis :...................................
Odour : Very faint ; irritation of eyes first noticed.
Odoriferous concentration : .... oz. per 1,000 cub. ft.
Physiological effect : Irritation and stinging of the eyes followed by copious flow of tears ; no skin irritation.
Protection required : Gas mask with filter.
Neutralisation :...
First aid : Wash eyes with boric acid.
Uses : Spray, bombs and shell.

Notes. A dark brown liquid, invisible in gaseous state, recognised by irritation to the eyes.

Respirator affords complete protection.

Common name of agent : H.C. MIXTURE.
Chemical symbol : (C_2Cl_6), Zinc and Zinc oxide (ZnO).
Classification : Screening agent.
Persistency :—
Winter : Only while burning.
Irritant concentration, ten minutes exposure : Smoke irritation negligible.
Intolerable concentration, ten minutes exposure : Smoke irritation negligible.
Lethal concentration, ten minutes exposure : Smoke harmless.
Melting-point : 363° F. Boiling point : 365° F.
Volatility : 2·85 oz. per 1,000 cub. ft. air at 68° F.
Vapour pressure : 0·22 mm. mercury at 68° F.
Vapour density compared with that of air : Vapour negligible; disseminated as solid.
Specific gravity of solid agent at 68° F. : 2·0.
Stability : Stable.
Solvents : Alcohol, ether (for hexachlorethane only).
Action on metals : None if dry.
Action with water : C_2Cl_6 slowly hydrolyses ; mixture ignites.
Product of hydrolysis : Smoke in air, ($ZnCl_2$) zinc chloride in water solution.
Odour : Acrid suffocating smoke.
Physiological effect : None from solid ; slightly suffocating action by heavy smoke.
Protection required : None.
Neutralisation : None needed.
First aid : None needed.
Uses : Burning type munitions only ; grenades ; candles ; smoke floats. Special air bombs.

Common name of agent: HYDROCYANIC ACID.
Chemical symbol: HCN (prussic acid).
Classification: Systemic toxic—casualty agent or paralysant.
Persistency—
Winter: Ten minutes in open; one hour in woods.
Summer: Five minutes in open; ten minutes in woods.
Irritant concentration, ten minutes exposure: 0·020 oz. per 1,000 cub. ft.
Intolerable concentration, ten minutes exposure: 0·030 oz. per 1,000 cub. ft.
Lethal concentration, ten minutes exposure: 0·200 oz. per 1,000 cub. ft.
Melting-point: 7° F. Boiling-point: 79° F.
Volatility: 873 oz. per 1,000 cub. ft. air at 68° F.
Vapour pressure: 603 mm. mercury at 68° F.
Vapour density compared with that of air: 0·93.
Specific gravity of solid agent at 68° F.: 0·75.
Solvents: $ASCl_2$, $SbCO_2$.
Stability: Stable when mixed with strong acid and dissolved in solvents.
Action on metals: None, except on copper, if dry; corrodes all if wet.
Action with water: Miscible, slowly decomposes.
Product of hydrolysis: Ammonium cyanide.
Odour: Like bitter almonds.
Odoriferous concentration: 0·0010 oz. per 1,000 cub. ft.
Physiological effect: Paralysis of central nervous system.
Protection required: Gas mask, absorbents only.
Neutralisation: None necessary.
First aid: Fresh air; cold water in face; artificial respiration.
Uses: Artillery shell.

Notes. A colourless, volatile liquid (non-persistent). Small amounts of vapour cause giddiness and headache. Larger doses unconsciousness and death.

Respirator affords complete protection.

Common name of agent : HYDROGEN SULPHIDE.
Chemical symbol : H_2S.
Classification : Paralysant—casualty agent.
Persistency—
Winter ....
Summer..
Irritant concentration, ten minutes exposure : ...... per 1,000 cub. ft.
Intolerable concentration, ten minutes exposure : .... oz. per 1,000 cub. ft.
Lethal concentration, ten minutes exposure : ...... oz. per 1,000 cub. ft.
Melting-point : $-123°$ F. Boiling-point : $-80°$ F.
Volatility : .... oz. per 1,000 cub. ft. air at 68° F.
Vapour pressure : .... mm. mercury at 68° F.
Vapour density compared with that of air : ....
Specific gravity of solid agent at 68° F. : ....
Stability : ....
Action on metals :.......................................
Action with water :......................................
Product of hydrolysis :..................................
Odour : Strong smell of bad eggs.
Odoriferous concentration : .... oz. per 1,000 cub. ft.
Physiological effect : Small doses, irritation of eyes and nose ; large doses, unconsciousness and death.
Protection required : Respirator.
Neutralisation :..
First aid :...
Uses :..

Notes. Non-persistent gas, lethal in large doses, but complete protection afforded by respirator.

Common name of agent: LEWISITE.
Chemical symbol: ($ClCH : CHAsCl_2$).
Classification: Vesicant—casualty agent.
Persistency—
Winter: One week.
Summer: Twenty-four hours in open; one week in woods.
Irritant concentration, ten minutes exposure: 0·0008 oz. per 1,000 cub. ft.
Intolerable concentration, ten minutes exposure: 0·0008 oz. per 1,000 cub. ft.
Lethal concentration, ten minutes exposure: 0·12 oz. per 1,000 cub. ft.
Melting-point: 8·6° F. Boiling-point: 374° F.
Volatility: 4·5 oz. per 1,000 cub. ft. air at 68° F.
Vapour pressure: 0·395 mm. mercury at 68° F.
Vapour density compared with that of air: 7·1.
Specific gravity of solid agent at 68° F.: 1·88.
Stability: Stable in steel containers.
Solvents: Mustard, chloropicrin, oil, alcohol.
Action on metals: None.
Action with water: Hydrolyses readily.
Product of hydrolysis: HCl, Ml oxide (ClCH) (CHAsO), very toxic.
Odour: Like geraniums, then biting.
Odoriferous concentration: 0·014 oz. per 1,000 cub. ft.
Physiological effect: Dissolves in skin, then burns and liberates Ml oxide, which poisons body.
Protection required: Gas masks and best of protective clothing.
Neutralisation: Alcoholic sodium hydroxide spray.
First aid: Wash with oils, hot water and soap, dry; first aid must be applied at once.
Uses: Airplane spray; airplane bombs and shell.

Notes. A colourless liquid when pure, brown in crude state, gives off an invisible gas. Causes severe irritation to nose—a useful warning.

Vapour is less effective on skin than mustard.

Liquid in eyes immediate and permanent injury; on skin blisters develop more rapidly than with mustard gas.

Respirator protects eyes and lungs only.

Lewisite readily reacts with water, giving a somewhat poisonous liquid, but poisonous only when drunk, and no longer yielding a poisonous vapour. This reaction is a matter of minutes only, especially when the weather is warm. Indeed, moist air would probably destroy the vapour fairly soon.[112]

Common name of agent : METHYL-DI-CHLOR-ARSINE (German : Methyldick).
Chemical symbol : (CH_3AsCl_2).
Classification : Vesicant, lung irritant—casualty agent.
Persistency
    Winter : Two to three hours.
    Summer : One hour.
Irritant concentration, ten minutes exposure : 0·002 oz. per 1,000 cub. ft.
Intolerable concentration, one minute exposure : 0·025 oz. per 1,000 cub. ft.
Lethal concentration, one minute exposure : 0·75 oz. per 1,000 cub. ft.
Melting-point : −66·6° F. Boiling-point : 269·6° F.
Volatility : 75 oz. per 1,000 cub. ft. air at 68° F.
Vapour pressure : 8·5 mm. mercury at 68° F.
Specific gravity of solid agent at 68° F. : 1·85.
Stability : Very stable.
Solvents : Organic solvents.
Action on metals : None.
Action with water : Slightly soluble.
Product of hydrolysis : None.
Odoriferous concentration : 0·0008 oz. per 1,000 cub. ft.
Physiological effect : Asthma, dyspnœa ; lung injurant, skin vesicant.
Protection required : Gas mask and best of protective clothing.
Neutralisation : Sodium hydroxide solution.
First aid : Wash with soap and water, then with sodium hydroxide (5 per cent.) ; wash eyes with boric acid.
Uses : Artillery and mortar shell.

Common name of agent: MUSTARD (H.S.).
Chemical symbol: $(CH_2ClCH_2)_2S$.
Classification: Vesicant; casualty agent.
Persistency (exceptional)—
Winter: Several weeks both in open and woods.
Summer: Twenty-four hours in open; one week in woods.
Irritant concentration, ten minutes exposure: Eye casualty concentration; 0·001 oz. per 1,000 cub. ft.
Intolerable concentration, one hour exposure: 0·001 oz. per 1,000 cub. ft. (Eye casualty.)
Lethal concentration, one hour exposure: 0·15 oz. per 1,000 cub. ft.
Melting-point: 57·9° F. Boiling-point: 422·6° F.
Volatility: 0·625 oz. per 1,000 cub. ft. air at 68° F.
Vapour pressure: 0·065 mm. mercury at 68° F.
Vapour density compared with that of air: 5·5.
Specific gravity of solid agent at 68° F.: 1·27.
Stability: Stable in steel container.
Solvents: Oils, alcohol, carbon tetrachloride and chloropicrin.
Action on metals: None.
Action with water: Slowly hydrolyses.
Product of hydrolysis: HCl and $(HOCH_2CH_2)S$, not toxic.
Odour: Like garlic or horse-radish.
Odoriferous concentration: 0·0013 oz. per 1,000 cub. ft.
Physiological effect: Dissolves in skin or lung tissue, then produces burns.
Protection required: Gas mask and protective clothing.
Neutralisation: Bleaching powder, 3 per cent. sodium sulphide (Na_2S) in water; steam; gaseous chlorine; or bury under moist earth.
First aid: Wash affected parts with kerosene or gasoline, then with strong soap and hot water; rub dry; rinse with hot clean water; agent must be removed within three minutes.
Uses: Airplane spray; airplane bombs and gas shell; as an oily liquid.

Notes. Dark brown to straw-colour liquid. The high boiling-point and low vapour pressure endows mustard gas with great persistency. Its high freezing-point maintains liquid frozen and undetected. It is extremely stable and is not readily destroyed except by strong chemicals such as chlorine or strong nitric acid. It readily dissolves in animal fats and readily penetrates into absorbent materials. It has great toxicity even in low concentrations.

Hypersensitivity may be induced after repeated burns.

Respirator protects eyes and lungs only.

Common name of agent : OLEUM (60 per cent.).
Chemical symbol : $(SO_3H_2SO_4)$.
Classification : Screening agent.
Persistency—
Winter : While container is operating.
Summer : While container is operating.
Irritant concentration, ten minutes exposure : Smoke irritation negligible.
Intolerable concentration, ten minutes exposure : Smoke irritation negligible.
Lethal concentration, ten minutes exposure : Smoke harmless.
Melting-point : 5° C. Boiling-point : Decomposes.
Volatility : Negligible.
Vapour pressure : Negligible.
Vapour density compared with that of air : ....
Specific gravity of solid agent at 68° F. : 1·99.
Stability : Stable if dry.
Action on metals : Corrosive unless dry.
Action with water : Hydrolyses.
Product of hydrolysis : H_2SO_3 and H_2SO_4.
Odour : Acrid suffocating smoke.
Physiological effect : Like strong acid.
Protection required : None.
Neutralisation : Wash freely with cold water.
Uses : Smoke grenades : airplane tanks.

Common name of agent: PHOSGENE (Carbonyl chloride).
Chemical symbol: $COCl_2$.
Classification: Lung injurant—casualty agent.
Persistency—
  Winter: Twenty minutes in open; two hours in woods.
  Summer: Ten minutes in open; forty-three minutes in woods.
Irritant concentration, ten minutes exposure: 0·005 oz. per 1,000 cub. ft.
Intolerable concentration, ten minutes exposure: 0·020 oz. per 1,000 cub. ft.
Lethal concentration, ten minutes exposure: 0·50 oz. per 1,000 cub. ft.
Melting-point: $-180°$ F. Boiling-point: 46·7° F.
Volatility: 6,370 oz. per 1,000 cub. ft. air at 68° F. at 1180 mm. Hg.
Vapour pressure: 1,180 mm. mercury at 68° F.
Vapour density compared with that of air: 3·5.
Specific gravity of solid agent at 68° F.: 1·38.
Stability: Stable in dry steel containers.
Solvents: Chlorine and chloropicrin.
Action on metals: None if dry; vigorous corrosion if wet.
Action with water: Hydrolyses rapidly.
Product of hydrolysis: HCl; CO_2.
Odour: Musty hay.
Odoriferous concentration: 0·0044 oz. per 1,000 cub. ft.
Physiological effect: Burns lower lung surfaces, causing œdema.
Protection required: Gas masks, absorbents in canister only.
Neutralisation: Steam hydrolyses; alkalies and amines react with C.G.
First aid: Keep patient quiet, administer heart stimulants; give oxygen in severe cases; treat like pleurisy.
Uses: Shells and cylinders.

Notes. A non-persistent (almost invisible) gas is rendered less effective by heavy rain, highly lethal.
Respirator affords complete protection.

Common name of agent : SOLID OIL.
Chemical symbol : Mixture of paraffin hydrocarbons.
Classification : Incendiary agent.
Persistency—
Winter : None.
Summer : None.
Irritant concentration, ten minutes exposure : None.
Intolerable concentration, ten minutes exposure : None.
Lethal concentration, ten minutes exposure : None.
Melting-point : 86° F. Boiling-point : None.
Volatility : None.
Vapour pressure : None.
Vapour density compared with that of air : None.
Specific gravity of solid agent at 68° F. : 0·9.
Stability : Stable.
Solvents : Organic solvents.
Action on metals : None.
Action with water : None.
Product of hydrolysis : None.
Odour : None.
Physiological effect : Burns like oil.
Protection required : Fireproof clothes.
Neutralisation : None.
First aid : Like hot liquid burn.
Uses : Bombs ; artillery shell.

Common name of agent : SULPHUR TRIOXIDE.
Chemical symbol : $(SO)_3$.
Classification : Screening agent.
Persistency—
Winter : While container is operating.
Summer : While container is operating.
Irritant concentration, ten minutes exposure : Smoke irritation negligible.
Intolerable concentration, ten minutes exposure : Smoke irritation negligible.
Lethal concentration, ten minutes exposure : Smoke harmless.
Melting-point : 104° F. Boiling-point : 113° F.
Volatility : Negligible.
Vapour pressure : 242·27 mm. mercury at 25° C.
Specific gravity of solid agent at 68° F. : 1·94.
Stability : Stable if dry.
Action on metals : Corrosive unless dry.
Action with water : Hydrolyses.
Product of hydrolysis : H_2SO_3 and H_2SO_4.
Odour : Acrid suffocating smoke.
Physiological effect : Hacking cough.
Protection required : None.
Neutralisation : Wash freely with cold water.
Uses : Artillery shell ; airplane spray.

Common name of agent : SULPHUR TRIOXIDE SOLUTION.
Chemical symbol : (SO_3) about 55 per cent., ($HClSO_3$) about 45 per cent. by weight.
Classification : Screening agent.
Persistency :
Winter : While container is operating.
Summer : While container is operating.
Irritant concentration, ten minutes exposure : Smoke irritation negligible.
Intolerable concentration, ten minutes exposure : Smoke irritation negligible.
Lethal concentration, ten minutes exposure : Smoke harmless.
Melting point : -22° F. Boiling-point : 8° F.
Volatility . . . . oz. per 1,000 cub. ft. air at 68° F.
Vapour pressure : . . . . mm. mercury at 68° F.
Vapour density compared with that of air : . . . .
Specific gravity of solid agent at 68° F. : 1·91.
Stability : Stable in steel containers .
Solvents : Strong sulphuric acid.
Action on metals : Vigorous corrosion if wet or in presence of moisture.
Action with water : Reacts violently like strong sulphuric acid.
Product of hydrolysis : Smoke in air, HCl and H_2SO_4 mixed in water. Solution as fog particles.
Odour : Acid or acrid.
Odoriferous concentration : . . . . oz. per 1,000 cub. ft.
Physiological effect : Liquid burns like strong acid, smoke causes pricking sensation on skin.
Protection required : None for ordinary smoke ; gas masks for high concentration. Only rubber gloves for handling liquid.
Neutralisation : Any alkali, solid or solution.
First aid : Like an acid burn.
Uses : Iron cylinders under gas pressure ; airplane spray tanks ; explosive shell.

Common name of agent : THERMITE.
Chemical symbol : ($Al + Fe_3O_4$).
Classification : Incendiary agent.
Persistency :
Winter : None.
Summer : None.
Irritant concentration, ten minutes exposure : None.
Intolerable concentration, ten minutes exposure : None.
Lethal concentration, ten minutes exposure : None.
Melting-point : 2732° F. Boiling-point : None.
Volatility : None.
Vapour pressure : None.
Vapour density compared with that of air : None.
Specific gravity of solid agent at 68° F. : 3·3.
Stability : Stable.
Solvents : None.
Action on metals : None.
Action with water : None.
Product of hydrolysis : None.
Odour : None.
Odoriferous concentration : .... oz. per 1,000 cub. ft.
Physiological effect : Burns like molten iron.
Protection required : Fireproof clothes.
Neutralisation : None.
First aid : Like ordinary burn.
Uses : Bombs ; artillery shell.

Common name of agent : TITANIUM TETRACHLORIDE.
Chemical symbol : ($TiCl_4$.)
Classification : Screening agent.
Persistency—
    Winter : Ten minutes in open.
    Summer : Ten minutes in open.
Irritant concentration, ten minutes exposure : Smoke irritation negligible.
Intolerable concentration, ten minutes exposure : Smoke irritation negligible.
Lethal concentration, ten minutes exposure : Smoke harmless.
Melting-point : $-9°$ F. Boiling-point : 277° F.
Volatility : 86·4 oz. per 1,000 cub. ft. air at 68° F.
Vapour pressure : 8·32 mm. mercury at 68° F.
Specific gravity of solid agent at 68° F. : 1·7.
Stability : Stable in steel containers when dry.
Solvents : Ethylene dichloride.
Action on metals : Vigorous corrosion by smoke. None by liquid on steel if dry.
Action with water : Hydrolyses.
Product of hydrolysis : Smoke in air ; $TiCl_4 \cdot 8H_2O$; then HCl and $Ti(OH)_4$.
Odour : Acrid.
Physiological effect : Liquid burns like strong acid ; vapours and smoke irritating to throat.
Protection required : None for ordinary smoke clouds, gas masks for heavy concentration only.
Neutralisation : Alkali ; solid or solution.
First aid : Wash with sodium bicarbonate solution, then with warm water ; treat burn with picric acid.
Uses : Artillery shell ; airplane spray, bombs and special munitions.

Common name of agent: WHITE PHOSPHORUS.
Chemical symbol: (P_4).
Classification: Screening agent and incendiary agent.
Persistency—

Winter: Depends upon size of burning particle; usually ten minutes or less in open.

Summer: Depends upon size of burning particle; usually ten minutes or less in open.

Irritant concentration, ten minutes exposure: Smoke irritation negligible.

Intolerable concentration, ten minutes exposure: Smoke irritation negligible.

Lethal concentration, ten minutes exposure: Smoke harmless.

Melting-point: 111° F. Boiling-point: 549° F.

Volatility: 0·1728 oz. per 1,000 cub. ft. air at 68° F.

Vapour pressure: 0·0253 mm. mercury at 68° F.

Vapour density compared with that of air: Vapour negligible; disseminated as a solid.

Specific gravity of solid agent at 68° F.: 1·83.

Stability: Stable, out of contact with oxygen.

Solvent: Carbon disulphide, ether, benzene.

Action on metals: None.

Action with water: None; stored under water in concrete tanks.

Product of hydrolysis: Smoke in air; phosphoric acid (H_3PO_4) dissolved in water.

Odour: Like matches.

Physiological effect: Solid particle burns flesh; vapours very poisonous, cause bone decay; smoke relatively harmless.

Protection required: None needed against smoke. Fireproof suits against burning particles.

Neutralisation: None needed; copper sulphate solution stops burning of particles as does water.

First aid: Apply copper sulphate solution; pull out solids; treat burn with picric acid; keep burning part under water until medical aid arrives if no copper sulphate is available.

Uses: Grenades; artillery shells; mortars and airplane bombs.

APPENDIX II

OFFICIAL TESTS ON A GAS-PROTECTED HOUSE

A detailed report on tests carried out on a gas-protected house is given in Home Office Circular—"Experiments in Anti-gas Protection of Houses," December 31st, 1937. (Price 2*d.* H.M. Stationery Office.)

The experiments were conducted by the Chemical Research Dept. under the ægis of a special sub-committee of the Chemical Defence Committee.

The house employed in the tests was a 6-roomed, 2-storey cottage, which was in sound repair but which had remained unoccupied for about fifteen years.

The house was situated in the shelter of a belt of trees, the conditions represented generally those obtaining in a town.

The house was enveloped in a lethal cloud of gas and the effects on animals and human occupants of the house were noted.

The results of the various tests can be summarised as below :—

TEST 1

Conditions

House unprotected, but doors and windows closed (no floor covering). Fire burning in the hearth. Over 1 ton of *chlorine gas* liberated 20 yards upwind of house thus enveloping it with lethal cloud for forty minutes.

Observations

Human beings occupying unprotected but closed room obliged to put on gas masks in seven minutes.

Conclusions

Closing doors and windows of house, otherwise unprepared, affords a considerable measure of protection and the ultimate use of respirators affords complete protection.

TEST 2

Conditions

House unprotected as before, but surrounded at a distance of 20 yards by large shallow trays of liquid *mustard "gas."* A fine spray of mustard gas also released 10 yards upwind of house. House enveloped in a lethal cloud for one hour.

Observations

Animals in unprotected room for twenty-one hours and none was seriously harmed. Animals outside the building were seriously affected.

Conclusions

Ordinary well-constructed buildings probably afford sufficient protection for animals against mustard cloud.

TEST 3

Conditions

The unprotected house as before was enveloped in an intense atmosphere of tear gas which was sprayed into the air 10 yards upwind for one hour.

Observations

Men 200 yards downwind from the house were incapacitated in one minute, but men who occupied the closed untreated house found no need to put on their respirators for the first thirteen minutes.

Conclusions

The unprotected house afforded considerable shelter to occupants without respirators and the subsequent use of respirators afforded complete protection.

TEST 4

Conditions

The unprotected house was enveloped for twenty minutes in a dense cloud of *arsenical smoke.*

Observations

The smoke penetrated the unprotected room and rendered the wearing of respirators necessary. Men 200 yards downwind were rapidly affected but the wearing of respirators afforded complete protection.

Conclusions

Unprotected buildings do not afford complete shelter against arsenical smokes for which respirators are necessary.

TEST 5

Conditions

One of the ground floor rooms, about 12 ft. square and against the windward outer wall, was gas protected as described in A.R.P. Handbook, No. 1. Two tons of chlorine were released in one hour 20 yards upwind.

Observations

Animals in unprotected rooms were killed, but those in the gas-protected room were unaffected.

Conclusions

Gas protected rooms afford complete protection against chlorine cloud for one hour.

TEST 6

Conditions

The house as already described had one gas protected room and was subjected to *mustard gas* spray and vapour as in Test No. 2.

Observations

Animals in the protected room for twenty hours showed no evidence of the effect at all Measurements of the concentration of the gas penetration showed the protection to be adequate for man for twenty hours.

Conclusions

Gas protected rooms give complete protection against the concentrations of mustard gas to be expected.

TEST 7

Conditions

A *tear gas* concentration as in Test No. 3 enveloped the house with one gas-protected room.

Observations

Men in the gas protected room did not need to use respirators.

Conclusions

A gas-protected room affords adequate protection against tear gas in the concentration likely to be met with in an emergency.

TEST 8

Conditions

The house with one gas protected room was subjected to a cloud of *arsenical smoke* for twenty minutes as described for Test No. 4.

Observations

The occupants ultimately had to wear gas masks to ensure comfort. Men with respirators traversed the densest part of the cloud without discomfort.

Conclusions

Arsenical smoke may penetrate into a gas protected room sufficiently to be detected but the wearing of civilian respirators affords complete protection.

Note. The conditions of the above trials were more severe than would normally be met in aerial bombardment of towns.

APPENDIX III

Summarised Minimal Air Requirements of Animals and Man of Average Weights (Quiet and at Rest)

Animal.	Fresh Air Ventilated into Shelters. Cub. ft. per min.		Unchanged Air Capacities of Closed Unventilated Shelters calculated on cub. ft. per min.	
	Normal Requirements for Indefinite Period.	Crush Requirements for 3 hours max.	Up to 12 hours Occupation.	Up to 3 hours Occupation.
Horse . .	1·35	0·74	9·5	3·8
Pig . .	0·39	0·22	2·7	1·1
Man . .	0·36	0·20	2·5	1·0
Dog . .	0·17	0·095	1·2	0·5
Goose . .	0·04	0·022	0·28	0·11
Cat . .	0·03	0·017	0·22	0·09
Rabbit . .	0·025	0·014	0·18	0·07
Hen . .	0·02	0·011	0·14	0·06

Note. Excited animals under considerable physical activity may require up to ten times the above air supplies.

APPENDIX IV

BIBLIOGRAPHY AND LIST OF REFERENCES

Ref. No. (See text).

1 No. 1 Personal Protection against Gas (1st Edition). (Price 6*d*., 8*d*. post free.) H.M. Stationery Office.
(A handbook primarily for members of air raid precautions services.)

2 No. 2 First Aid for Gas Casualties (2nd Edition). (Price 4*d*., 5*d*. post free.)
(A handbook designed primarily for services giving first aid to air raid casualties.)

3 No. 3 Medical Treatment for Gas Casualties (price 6*d*., 8*d*. post free.)
(A handbook for hospitals, doctors and nurses.)

4 No. 4 Decontamination of Materials (price 6*d*., 7*d*. post free).
(Decontamination of streets, buildings and their contents, vehicles and plant.)

5 No. 5 Structural Defence. H.M. Stationery Office. (Price 2/-.)

6 No. 6 Air Raid Precautions in Factories and Business Premises. (Price 6*d*., 7*d*. post free.)
(A handbook designed primarily for the guidance of occupiers of such premises.)

7 No. 7 Anti-Gas Precautions for Merchant Shipping (2nd Edition). (Price 3*d*., 4*d*. post free.)
(Includes certain recommendations to Port Authorities.)

8 A special handbook is also being prepared for Householders.

9 No. 1 Organisation of Air Raid Casualties Services. Price 6*d*. (7*d*.). (Memorandum.)

10 No. 2 Rescue Parties and Clearance of Débris. Price 2*d*. (2½*d*.). (Memorandum.)

11 No. 3 Organisation of Decontamination Services. Price 2*d*. (2½*d*.). (Memorandum.)

12 No. 4 Air Raid Wardens. Price 2*d*. (2½*d*.). (Memorandum.)

13 No. 4 Anti-Gas Training. Price 4*d*. (5*d*.). (Memorandum.)

14 The Protection of Food-stuffs against Poison Gas. Price 2*d*.

15 Home Office Circular—Air Raid Precautions, 9th July, 1935. Price 2*d*.

16 Home Office Circular—Anti-Gas Training, 24th February, 1936. Price 1*d*.

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21 Home Office Circular—Certification mark for Respirators giving protection against Poison Gases used in War. Price 3*d*.
22 Home Office Circular—Certification mark for Filtration Plants giving protection against Poison Gases used in War. Price 2*d*.
23 Home Office (Fire Brigades Division) Circular, 23rd February, 1937. Price 2*d*.
24 Home Office Circular—Air Raid Precautions: Badges for Volunteers, 23rd February, 1937. Price 1*d*.
25 Home Office Circular—Air Raid Precautions, 27th February, 1937. Price 1*d*.
26 Home Office Circular—Anti-Gas Training, 8th July, 1937. Price 1*d*.
27 Home Office Circular—Air Raid Precautions, 31st May, 1937. Price 1*d*.
28 Home Office Circular—First Aid Posts, 10th December, 1937. Price 1*d*.
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30 Home Office Circular—Experiments in Anti-Gas Protection of Houses, 31st December, 1937. Price 2*d*.
31 Home Office Circular—Sketch of emergency Fire Brigade Organisation for a Hypothetical Town. Price 2*d*.
32 Air Raid Precautions Act, 1937. Price 3*d*.
33 Home Office Memorandum on Emergency Fire Brigade Organisation. Price 6*d*.
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114 Report of the Committee on Air Raid Precautions. 1*s.* Inst. Struct. E.
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116 No. 8. The Air Raid Warning System. Price 3*d.* (4*d.*). (Memorandum.)

117 No. 9. Notes on Training and Exercises. Price 2*d*. (2½*d*.). (Memorandum.)
118 No. 10. Provisions of Air Raid Shelters in Basements. Price 4*d*. (Memorandum.)
119 Emergency Medical Services: No. 1. Structural and other Precautions against Air Raid Risks in Hospitals. Price 3*d*. (3½*d*.)
120 Emergency Medical Services: No. 2. Emergency Hospital Organisation. Price 6*d*. (7*d*.).
121 Home Office Circular—Emergency Fire Brigade Organisation. December 15th, 1937. Price 1*d*. (1½*d*.).
122 Home Office Circular—General Model Schemes, March 28th, 1938. Price 1*d*. (1½*d*.)
123 Home Office Circular—Local Storage and Distribution of Civilian Respirators, July 6th, 1938. Price 6*d*. (7*d*.).
124 Home Office Circular—Air Raid Precautions (Approval of Expenditure) Provisional Regulations, July 29th, 1938. Price 1*d*. (1½*d*.).
125 Home Office Circular—Auxiliary Fire Services Badge, August 24th, 1938. Price 2*d*. (2½*d*.).
126 Home Office Circular—Construction of Stretcher-carrying Fitment for the Conversion of Commercial Vehicles for use as Ambulances, September 23rd, 1938. Price 1*d*. (1½*d*.).
127 Home Office Circular—Maps for Use in Connection with A.R.P. Schemes, November 30th, 1938. Price 2*d*. (2½*d*.).
128 Home Office Circular—Badges for Volunteers, December 20th, 1938. Price 1*d*. (1½*d*.).
129 Home Office Circular—Enrolment of Auxiliary Fire Service Volunteers under National Service Campaign, January 23rd, 1939. Price 1*d*. (1½*d*.).
130 Home Office Circular—Organisation of Air Raid General Precautions, January 26th, 1939. Price 2*d*. (2½*d*.).
131 Home Office Circular—Air Raid General Precautions Schemes in Rural Districts, January 26th, 1939. Price 1*d*. (1½*d*.).
132 Home Office Circular—Courses of Instruction in First Aid, January 26th, 1939. Price 2*d*. (2½*d*.).
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138 Rating and Valuation Act, 1938. Price 1*d*. (1½*d*.).

139 A.R.P. (Approval of Expenditure) Provisional Regulations, 1938. Price, 3*d.* (3½*d.*).

140 Special Points (under the above Regulations) arising under Fire Precautions Schemes, September, 1938. Price 2*d.* (2½*d.*).

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142 Auxiliary Fire Service Uniforms and Equipment Specifications. Price 9*d.* (10*d.*).

143 Certification Mark for Respirators of General Service type giving protection against Poison Gases used in War (Supplement to No. 21 in respect of Respirators of the Civilian and Civilian Duty Type). Price 3*d.* (3½*d.*).

144 Emergency Fire Brigade Appliances. Price 9*d.* (10*d.*).

145 Emergency Fire Brigade Measures in Rural Districts. Price 3*d.* (3½*d.*).

146 Pamphlet on Garden Trenches. Price 1*d.* (1½*d.*).

147 General Precautions (Model) Scheme.

148 Protection of your Home against Air Raids. Price 1*d.* (1½*d.*).

149 Specifications, etc., in regard to the Permanent Lining of Trenches. Price 4*d.* (5*d.*).

150. Stages in the Preparation of a Local Authority's Air Raid General Precautions Scheme, July 1938. Price 2*d.* (2½*d.*).

151 Training of Air Raid Wardens. Price 2*d.* (2½*d.*).

152 A.R.P. for Government Contractors. Price 4*d.*

153 Directions for the Erection of Domestic Surface Shelters. Price 2*d.* (2½*d.*).

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179 Essential Buildings and Plant (Repair of War Damage Act), 1939. H.M. Stationery Office. 3*d*. net.
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APPENDIX V

METRIC EQUIVALENTS OF BRITISH UNITS

Linear Measure

British Units.	Metrical Equivalents.	Metrical Units.	British Equivalents.
1 in.	= 2·5399541 cm.	1 millimetre	= 0·03937 in.
1 in.	= 0·02539954 metre	1 centimetre	= 0·393708 ..
1 ft.	= 0·3047945 ..	1 metre	= 39·37079 ..
1 yd.	= 0·91438348 ..	1 ..	= 3·2808992 ft.
1 fathom	= 1·82876696 metres.	1 ..	= 1·0936331 yds.
1 pole	= 5·02911 ..	1 kilometre	= 1093·6331 ..
1 chain	= 20·116437 ..	1 ..	= 49·71050 chains.
1 furlong	= 201·16437 ..	1 ..	= 3280·8992 ft.
1 mile	= 1609·31493 ..	1 ..	= 0·6213824 mile.

Square Measure

British Units.	Metrical Equivalents.	Metrical Units.	British Equivalents.
1 sq. in.	= 6·451367 sq. cm.	1 sq. cm.	= 0·15500590 sq. in.
1 sq. ft.	= 0·09289968 sq. metre.	1 sq. metre	= 10·7642004 sq. ft.
1 sq. yd.	= 0·8360971 ..	1 sq. metre	= 1·1960333 sq. yds.
1 sq. yd.	= 0·008360971 are	1 are	= 119·60333 sq. yds.
1 acre	= 0·404671 hectare.	1 hectare	= 2·47114 acres.
1 sq. mile	= 258·98945 hectares.	1 ..	= 0·0038612 sq. mile.

Cubic Measure

British Units.	Metrical Equivalents.	Metrical Units.	British Equivalents.
1 cu. in.	= 16·3861759 cu. cm.	1 cu. cm.	= 0·06102705 cu. in.
1 cu. ft.	= 0·02831531 cu. metre	1 cu. metre	= 35·3163074 cu. ft.
1 cu. yard	= 0·764451342 ..	1	= 1·30802151 cu. yd.

Capacity

British Units.	Metrical Equivalents.	Metrical Units.	British Equivalents.
1 cu. in.	= 16·386176 millilitres.	1 millilitre	= 0·061027 cu. in.
1 ,, ,,	= 1·6386176 centilitres.	1 centilitre	= 0·61027 ,, ,,
1 gill	= 14·1983 ,,	1 ,,	= 0·07043 gill.
1 pint	= 0·567932 litre.	1 litre	= 1·76077 pints.
1 quart	= 1·135864 litres.	1 ,,	= 0·880387 quart.
1 gallon	= 4·543458 ,,	1 litre	= 0·2200967 gallon.
1 ,,	= 0·4543458 dekalitre.	1 dekalitre	= 2·20097 gallons.
1 bushel	= 3·634766 dekalitres.	1 ,,	= 0·275121 bushel.
1 ,,	= 0·3634766 hectolitre.	1 hectolitre	= 2·75121 bushels.

Weight

British Units.	Metrical Equivalents.	Metrical Units.	British Equivalents.
Avoirdupois.			Avoirdupois.
1 grain	= 64·79895 milligrammes.	1 milligramme	= 0·01543235 grain.
1 ,,	= 6·479895 centigrammes.	1 centigramme	= 0·1543235 ,,
1 ,,	= 0·06479895 gramme.	1 gramme	= 15·43235 grains.
1 ounce	= 28·34954 grammes.	1 ,,	= 0·0352739 ounce.
1 ,,	= 0·02834954 kilogramme.	1 kilogramme	= 35·27394 ounces.
1 pound	= 0·45359265 ,,	1 ,,	= 2·20462125 pounds
1 cwt.	= 0·50802377 quintal.	1 quintal	= 1·96841 cwts.
1 ton	= 1·01604754 milliers or tonnes.	1 millier or tonne	= 0·98420591 ton.
		1 millier or tonne	= 2204·6 pounds.

MISCELLANEOUS COMPOUND MEASURES

British Units.	Metrical Equivalents.	Metrical Units.	British Equivalents.
1 ft. per sec.	= 0·3048 metre per sec.	1 metre per sec.	= 3·2808 ft. per sec.
1 ft. per min.	= 0·3048 metres per min.	1 metre per min.	= 3·2808 ft. per min.
1 mile per hour	= 1·6093 km. per hour.	1 km. per hr.	= 0·6214 mile per hour.
1 lb. per ft.	= 1·48816 kg. per metre.	1 kg. per metre	= 0·67196 lb. per ft.
1 lb. per yd.	= 0·49606 kg. per metre.	1 kg. per metre.	= 2·01587 lb. per yd.
1 lb. per sq. in.	= 0·07031 kg. per sq. cm.	1 kg. per sq. cm.	= 14·22282 lb. per sq. in.
1 lb. per sq. ft.	= 4·88261 kg. per sq. metre.	1 kg. per sq. metre	= 0·20481 lb. per sq. ft.
1 ton per sq. in.	= 1·57494 kg. per sq. mm.	1 kg. per sq. mm.	= 0·63495 ton per sq. in.
1 ton per sq. ft.	= 10·93704 tonnes per sq. metre.	1 tonne per sq. m.	= 0·09143 ton per sq. ft.
1 lb. per cu. in.	= 0·02768 kg. per c.cm.	1 kg. per cu. cm.	= 36·1254 lbs. per cu. in.
1 lb. per cu. ft.	= 16·019 kg. per cu. metre.	1 kg. per cu. metre	= 0·0624245 lb. per cu. ft.
1 lb. per cu. yd.	= 0·5933 kg. per cu. metre.	1 kg. per cu. metre	= 1·68546 lbs. per cu. yd.
1 lb. per gall.	= 0·09983 kg. per litre.	1 kg. per litre	= 10·0166 lbs. per gall.

APPENDIX VI

CLASSIFIED BUYERS' GUIDE

AIR RAID PRECAUTIONS EQUIPMENT

Agfab Ltd.
Air Defence Equipment Service.
Angus, George, & Co. Ltd.
Beattie, S. N., & Co. Ltd.
Francis, T., & Sons.
Helmets Ltd.
L. & G. Fire Appliance Co. Ltd.
Morris, John, & Sons Ltd.
National Fire Protection Co. Ltd., The.
Pyrene Co. Ltd., The.
Roberts, McLean & Co. Ltd.
Siebe, Gorman & Co. Ltd.
Sigmund Pumps (Great Britain) Ltd.
Sutcliffe, Speakman & Co. Ltd.
Valor Co. Ltd.
Wallach Bros. Ltd.
Woodhouse Products Ltd.

AIR RAID SHELTERS (UNIT TYPE)

Air Conditioning Corporation (Jeffreys) Ltd.
Alexandra Stone Co. Ltd.
Allen, W. G., & Sons (Tipton) Ltd.
Attoc Blocks Ltd.
Bilham & Davis.
Booth, John, & Sons (Bolton) Ltd.
Braby, F., & Co. Ltd.
Bristol Stone and Concrete Co.
Commercial Structures Ltd.
Concrete Ltd.
Concrete Pipes and Manholes Ltd.
Constructors Ltd.
Costain, Richard, Ltd.
Croft Granite Brick and Concrete Co.
Darlaston Galvanised Hollow Ware Co. Ltd.
Ductile Steels Ltd.
Ellis, John, & Sons Ltd.
Expanded Metal Co. Ltd.
Girlings Ferro-Concrete Co. Ltd.
Guest, Keen, Baldwins Iron and Steel Co. Ltd.

AIR RAID SHELTERS (UNIT TYPE)—*continued.*

Head, Wrightson & Co. Ltd.
Hunziker (Great Britain) Ltd.
Lewis Construction.
Melville, Dundas and Whitson Ltd.
Muirhead Shelters Licences Ltd.
Nissen Buildings Ltd.
Norcon Ltd.
R.I.W. Protective Products Ltd., The.
Scaffolding (Great Britain) Ltd.
Self Sentering Expanded Metal Co. Ltd.
Sharp, Jones & Co. Ltd.
Solent Engineering Co. Ltd.
Spun Concrete Ltd.
Stanton Ironworks Ltd.
Steel Ceilings Ltd.
Steel Scaffolding Co. Ltd.
Stent Precast Concrete Ltd.
Trianco Ltd.
Trollope & Colls Ltd.
Trussed Concrete Steel Co. Ltd.
Universal Floors Ltd.
Wallis, G. E., & Sons Ltd.
Wates Ltd.
Westwood, Jos., & Co. Ltd.
Wilmot & Co., S. M. Ltd.
Wright, Samuel, & Co. Ltd.

AIR RAID SHELTERS (IN SITU)

Anti-Bomb Constructions Ltd.
Bracey & Clark Ltd.
Bradford, F., & Co. Ltd.
British Air Raid Shelters Ltd.
Concrete Ltd.
Expanded Metal Co. Ltd., The.
Fairweather & Ranger.
Francois Cementation Co. Ltd.
Hall, Matthew, & Co. Ltd.
Holland & Hannen and Cubitts.
Liversedge Reinforced Concrete Engineering Co. Ltd., The.
Matthews & Mumby Ltd.
Mowlem, John, & Co. Ltd.
Muirhead Shelters Licences, Ltd.
Norcon Ltd.

AIR RAID SHELTERS (IN SITU) — *continued*.
Parker Construction Co.
Rice & Son Ltd.
Rom River Co. Ltd., The.
Self Sentering Expanded Metal Co. Ltd.
Stanton Ironworks Ltd.
Taylor Woodrow Construction Ltd.
Universal Floors Ltd.

ALARM SYSTEMS (INTERNAL)
Associated Fire Alarms Ltd.
Burgot Alarms Ltd.
Gent & Co. Ltd.

ALARM SYSTEMS (STREET)
Associated Fire Alarms Ltd.
Automatic Telephone & Electric Co. Ltd.
Carter & Co. (Nelson) Ltd.
Gent & Co. Ltd.
Standard Telephones and Cables Ltd.
Steljes Fire Alarms and Electrical Appliances Co. Ltd.
Walter's Electrical Manufacturing Co. Ltd.

AMBULANCES
Austin Motor Co. Ltd.
Lomas, Herbert Ltd.
Morris Commercial Cars Ltd.
Vauxhall Motors Ltd.
Wilson & Stockall Ltd.
Woodhouse Products Ltd.

AMBULANCE BEDS
D. Mosely & Son, Ltd.

ASBESTOS PROTECTIVE EQUIPMENT
Angus, George, & Co. Ltd.
Beldam Asbestos Co. Ltd.
Bell's Asbestos and Engineering Supplies Ltd.
British Belting and Asbestos Ltd.
Engineering Stores and Services Ltd.
L. and G. Fire Appliance Co. Ltd.
Roberts, McLean & Co. Ltd.
Siebe, Gorman & Co. Ltd.

ASPHALT (GAS RESISTING)
Excel Asphalte Co. Ltd.
Field & Palmer Ltd.
Limmer and Trinidad Lake Asphalt Co. Ltd.
Natural Asphalt Mine-owners and Manufacturers' Council.
Permanite Ltd.

BATTERIES
Nife Batteries Ltd.

BELLS (FIRE ENGINE)
Associated Fire Alarms Ltd.
Francis, F., & Sons.

BINDERS, HOSE COUPLING
Merryweather & Sons Ltd.

BLINDS (DARK)
Artistic Blind Co.
Avery, Jos., & Co.
Blackout Fabrics Ltd.
Greyfriars Products Ltd.
James & Son.
Williamson, J., & Son Ltd.

BOOTS, Etc.
Adams Bros. (Raunds) Ltd.
Angus, George, & Co. Ltd.
Cotton Oxford Shoemakers.

BRANCH PIPES AND NOZZLES
Angus, George, & Co. Ltd.
British Hose and Appliances Co. Ltd.
Dixon, S., & Son Ltd.
Knowsley Cast Metal Co. Ltd.
Merryweather & Sons Ltd.
Morris, John, & Sons Ltd.
Morris, John ('Firemoss') Ltd.
Pyrene Co. Ltd., The.
Roberts, McLean & Co. Ltd.
Simonis & Bremner.
South Wales (Fire Protection) Engineers Ltd., The.
Universal Nozzle Co.
Winn, Charles, & Co. Ltd.
Woodhouse Products Ltd.

BREATHING APPARATUS AND RESPIRATORS
Angus, George, & Co. Ltd.
Antifyre Ltd.
British Civilian Gas Mask and Appliances Ltd., The.
British Draeger Co. Ltd.
L. & G. Fire Appliance Co. Ltd.
Merryweather & Sons Ltd.
Roberts, McLean & Co. Ltd.
Russell Bros.
Savalife Ltd.
Siebe, Gorman & Co. Ltd.
Simonis & Bremner.
Wallach Bros.

BREECHINGS
British Hose and Appliances Co. Ltd.

BUCKETS (FIRE)
Angus, George, & Co. Ltd.
Automatic Sprinkler Co. Ltd., The.
Engineering Stores and Services Ltd.
Taylor, John, Dunford & Co. Ltd.

BUCKETS (CANVAS)
Angus, George, & Co. Ltd.
Simonis & Bremner.

CARBON DIOXIDE EXTINGUISHERS
Pyrene Co. Ltd., The.

CENTRAL CONTROL SYSTEMS
Automatic Telephone & Electric Co., Ltd.

CORRESPONDENCE SCHOOLS, Etc.
Bennett College, The.
International Correspondence Schools Ltd.
Metropolitan College.

COUPLINGS
British Hose and Appliances Co. Ltd.
Dixon, S., & Son Ltd.
Knowsley Cast Metal Co. Ltd.
L. & G. Fire Appliance Co. Ltd.
Morris, John, & Sons Ltd.
Morris, John (Firesnow) Ltd.
Pyrene Co. Ltd., The.

DAMS (CANVAS)
Angus, George, & Co. Ltd.
Simonis & Bremner.

DECONTAMINATION EQUIPMENT
Auld Bruce, H., & Co. Ltd.
Braby, Fredk., & Co. Ltd.
British Hose and Appliances Co. Ltd.
Butterfield, W. P. Ltd.
Imperial Chemical Industries Ltd.
Jardine, Whyte & Co. Ltd.
Lister, Bros. Ltd.
Solent Engineering Co. Ltd.
Universal Nozzle Co.
Winn, Charles, & Co. Ltd.
Wright, John, & Co. Ltd.

DECONTAMINATION VEHICLES
Dennis Bros. Ltd.
Eagle Engineering Co. Ltd.
Karrier Motors Ltd.
Scammell Lorries Ltd.
Shelvoke and Drewry Ltd.
Tuke and Bell Ltd.

DE-SCALERS
Clensol Ltd.
Eric Engineering Co. Ltd.

DOOR OPENERS
Simonis and Bremner.

DOORS (GAS TIGHT)
Air Conditioning Corporation (Jeffreys) Ltd.
Booth & Son (Bolton) Ltd.
Braby, Fredk., & Co. Ltd.
Caston & Co. Ltd.
Chatwood Safe Co. Ltd.
Costain, Richard Ltd.
Crittall Manufacturing Co. Ltd.
Durasteel Roofs Ltd.
Flexo Plywood Industries Ltd.
Gardner & Co. Ltd.
Greenwood's Ventilating Co. Ltd.
Haywards Ltd.
Nissen Buildings Ltd.
Norris, F. A., & Co. Ltd.
Sandell, Joseph, & Co. Ltd.
Solent Engineering Co. Ltd.
Tann, John Ltd.
Universal Steel Door Ltd.

DRENCHER SYSTEMS
The Automatic Sprinkler Co. Ltd.

DRYING MACHINES
Lister Bros. Ltd.

ESCAPE GRATINGS
Crittall Manufacturing Co. Ltd.

ESCAPES (AUTOMATIC)
Beattie, S. N., & Co. Ltd.
Kerr, John, & Co. (M/cr.) Ltd.
Safety Automatic Fire Escapes Ltd.

ESCAPES (STAIR)
General Construction and Engineering Co. Ltd.
Norris, F. A., & Co. Ltd.
Sebry's Architectural Ironworks.

ESCAPES (TURNTABLE LADDER)
Dennis Bros. Ltd.
Kerr, John, & Co. (M/cr.) Ltd.
Leyland Motors Ltd.
Merryweather & Sons Ltd.
Morris, John, & Sons, Ltd.
Morris, John (Firesnow) Ltd.
Simonis & Bremner.

ESCAPES (WHEELED)
Merryweather & Sons Ltd.
Morris, John, & Sons Ltd.
Simonis & Brenmer.
Taylor, John, Dunford & Co. Ltd.

EXTINGUISHERS

Antifyre Ltd.
Associated Fire Alarms Ltd.
British Hose and Appliance Co. Ltd.
Clarke and Vigilant Sprinklers Ltd.
Dixon, S., & Son Ltd.
Engineering Stores and Services Ltd.
Enright Fire Services and Supplies Ltd.
Fire Appliance Co. (Dick's Patents).
Foamite Ltd.
Fyrone Co. Ltd.
General Fire Appliance Co. Ltd.
Haslams (Sheet Metal Workers) Ltd.
Kerr, John, & Co. (M/cr.) Ltd.
L. and G. Fire Appliance Co. Ltd.
Mather & Platt, Ltd.
Merryweather & Sons, Ltd.
William Miller (Glasgow) Ltd.
Minimax Ltd.
Morris, John, & Sons Ltd.
National Fire Protection Co. Ltd., The.
Nuswift Engineering Co. Ltd., The.
Pyrene Co. Ltd., The.
Ravenhose Ltd.
Read & Campbell Ltd.
Riley & Co.
Safety Automatic Fire Escapes Ltd.
Simonis & Bremner.
Sinclair & Co.
South Wales (Fire Protection) Engineers Ltd., The.
Taylor, John, Dunford & Co. Ltd.
Valor Co. Ltd.
Walker & Holroyd (1933) Ltd.
Walker Perfection Fire Extinguisher Ltd., The.
Wallach Bros. Ltd.
Winhams Ltd.
Winn, Charles, & Co. Ltd.

FILTRATION PLANT (ANTI-GAS)

Abair Engineering Ltd.
Air Conditioning Corporation (Jeffreys) Ltd.
Air Control Installations Ltd.
Airguard Ltd.
Allday, William, & Co. Ltd.
Braby, Fredk., & Co. Ltd.
British Draeger Co. Ltd.
Buck & Hickman Ltd.
Candar Air Conditioning Co. Ltd.
Carrier Engineering Co. Ltd.
Conjoint Constructions Ltd.
Crittall, Richard, & Co. Ltd.
Davidson & Co. Ltd.

FILTRATION PLANT (ANTI-GAS) *continued*

Greenwoods Ventilating Co., Ltd.
Keith, Blackman Ltd.
Lamson Engineering Co. Ltd.
Mellor, Bromley & Co., Ltd.
Reeve, J. E., & Son Ltd.
Standard & Pochin Bros. Ltd.
Sturtevant Engineering Co. Ltd.
Sulzer Bros. (London) Ltd.
Sutcliffe, Speakman & Co., Ltd.
Tann, John Ltd.
Tarpen Engineering Co. Ltd.
Vacuum Refrigeration Ltd.
Wallach Bros. Ltd.

FIRE DOORS

Booth, John, & Sons.
Chatwood Safe Co. Ltd.
Durasteel Roofs Ltd.
Haywards Ltd.
Mather & Platt Ltd.
Tann, John, Ltd.

FIREPROOF FLOORING

Attoc Blocks Ltd.
Imperial Chemical Industries Ltd.
King, J. A., & Co. Ltd.
Smith's Fireproof Floors Ltd.
Trianco Ltd.
Uneek Constructions Ltd.
Universal Floors Ltd.

FIREPROOFERS, STRUCTURAL TIMBER AND TEXTILE

Asbestos Fireproof and General Paint Co. Ltd.
Calder, John, & Co. Ltd.
Crayford Fireproofing Co. Ltd.
Imperial Chemical Industries Ltd.
Newalls Insulation Co. Ltd.
Perrott & Perrott Ltd.
Roberts, J. W., Ltd.
Timber Fireproofing Co. Ltd.
Walker Solutions Ltd.
Zist Ltd.

FIREPROOF PANELLING

Brown & Tawse Ltd.
BX Plastics Ltd.
Cellactite and British Uralite Ltd.
Durasteel Roofs Ltd.
Gabriel Wade & English Ltd.
King, J. A., & Co. Ltd.
Plybestos Ltd.
Smith, Stanley, & Co.
Tucker Armoured Plywood Co. Ltd.
Venesta Ltd.

FIRST AID EQUIPMENT
British Hose and Appliances Co. Ltd.
Engineering Stores and Services Ltd.
Knowsley Cast Metal Co. Ltd.
Winn, Charles, & Co. Ltd.

FIRST AID SUPPLIES (MEDICAL)
Angus, George, & Co. Ltd.
Boots Manufacturing Ltd.
British Drug Houses Ltd.
British Oxygen Co. Ltd.
Cuxson, Gerard & Co. Ltd.
Dalmas, A. de St., & Co. Ltd.
Inhalation Institute Ltd.
Maw, S., Son & Sons Ltd.
Minimax Ltd.
Siebe, Gorman & Co. Ltd.
Sutcliffe, Speakman & Co. Ltd.
Taylor, Edward, Ltd.
Tor Equipment Co. Ltd.
Wallach Bros. Ltd.
Woolley, James, Sons & Co. Ltd.

FIRST AID TENDERS
Leyland Motors Ltd.

FLOODLIGHTS
Francis, T., & Sons.
Morris, John, & Sons Ltd.
Simonis & Bremner.
Tilley Lamp Co., The.

FOAM EXTINGUISHERS
Foamite Ltd.
Minimax Ltd.
Morris, John, & Sons Ltd.
Pyrene Co. Ltd., The.
South Wales (Fire Protection) Engineers Ltd., The.

FOAM GENERATORS
Foamite Ltd.
Merryweather & Sons Ltd.
Pyrene Co. Ltd., The.

GAS DETECTING UNITS
National Fire Protection Co. Ltd., The.

GAS-PROOF DOORS, SHUTTERS AND WINDOWS
Air-Conditioning Corporation (Jeffreys) Ltd.
Braby, Fredk. G., & Co.
Cellactite and British Uralite Ltd.
Conjoint Constructions Ltd.
Crittall Manufacturing Co. Ltd.
Greenwoods Ventilating Co. Ltd.
Guildford Glass Works Ltd.
Norris, F. A., & Co. Ltd.
Solent Engineering Co. Ltd.

GAS-PROOFING MATERIALS
A.G.P. Co. Ltd.
Dunlop Rubber Co. Ltd.
Gas Proofing Co. Ltd.
Industrial Controls Ltd.
Jones, John (Steelcrete) Ltd.
Mollex Metals Ltd.
Sealocrete Products Ltd.
Siebe, Gorman & Co. Ltd.
Sorbo Ltd.
Winn & Coales Ltd.

GLASS (SAFETY)
British Indestructo Glass Ltd.
Mouldright Ltd.
Nicholls & Clarke Ltd.
Pilkington Bros. Ltd.
Triplex Safety Glass Co. Ltd.

HELMETS (FIREMEN'S)
Angus, George, & Co. Ltd.
Dixon, S., & Son Ltd.
Helmets Ltd.
Hendry, James, Ltd.

HOSE (DELIVERY)
Angus, George, & Co. Ltd.
British Hose and Appliances Co. Ltd.
Dixon, S., & Son Ltd.
Lewis & Tylor Ltd.
L. & G. Fire Appliance Co. Ltd.
McGregor & Co.
Morris, John, & Sons Ltd.
Moseley, David, & Sons Ltd.
Pyrene Co., Ltd., The.
Ravenhose Ltd.
Reddaway, F., & Co. Ltd.
Rose Hose Co. Ltd., The Wm.
Simonis & Bremner.
Taylor, John, Dunford & Co. Ltd.
Walker Perfection Fire Extinguisher Ltd., The.

HOSE (FIRST AID)
Ravenhose Ltd.
Taylor, John, Dunford & Co. Ltd.

HOSE (SUCTION)
Dixon, S., & Sons Ltd.
Ravenhose Ltd.
Reddaway, F., & Co. Ltd.

HOSE CARTS
Dixon, S., & Son Ltd.
Morris, John, & Sons Ltd.
Morris, John (Firesnow) Ltd.

HOSE CRADLES
Morris, John, & Sons Ltd

HOSE RAMPS
South Wales (Fire Protection) Engineers Ltd., The.

HOSE REELS
Angus, George, & Co. Ltd.
British Hose and Appliances Co. Ltd.
Dixon, S., & Son Ltd.
Kerr, John, & Co. (M/cr.) Ltd.
Knowsley Cast Metal Co. Ltd.
Morris, John, & Sons Ltd.
Morris, John (Firesnow) Ltd.
National Fire Protection Co. Ltd., The.
Pyrene Co. Ltd., The.
Safety Automatic Fire Escapes Ltd.
Taylor, John, Dunford & Co. Ltd.
Winn, Charles, & Co. Ltd.

HYDRANT KEYS AND BARS
Beattie, S. N., & Co. Ltd.
Ravenhead Ltd.
Simonis & Bremner.

HYDRANTS
Blakeborough, J., & Sons Ltd.
Glenfield & Kennedy Ltd.
Guest & Chrimes Ltd.
Ham, Baker & Co. Ltd.

INSTRUCTIONAL EQUIPMENT
Roberts, McLean & Co. Ltd.
Siebe, Gorman & Co. Ltd.
Universal Air Defence Services.
Woodhouse Products Ltd.

JUMPING SHEETS
Dixon, S., & Son Ltd.
Simonis & Bremner.

LADDERS (EXTENSION AND POMPIER)
Dennis Bros. Ltd.
Dixon, S., & Son Ltd.
Drew, Clark & Co.
Kerr, John, & Co. (M/cr.) Ltd.
Merryweather & Sons Ltd.
Morris, John, & Sons Ltd.
Morris, John (Firesnow) Ltd.
Simonis & Bremner.
South Wales (Fire Protection) Engineers Ltd., The.

LADDERS (MISCELLANEOUS)
Angus, George, & Co. Ltd.
Beattie, S. N., & Co. Ltd.
Gravity Ladders Ltd.
Kenyon, William, & Sons Ltd.
Taylor, John, Dunford & Co. Ltd.

LAMPS (PORTABLE)
Beattie, S. N., & Co. Ltd.
Ever Ready Co. (Great Britain) Ltd.
Nife Batteries Ltd.
Nox Electric Co. Ltd., The.
Smith, S., & Sons (M.A.) Ltd.
Webb Lamp Co. Ltd.
Woodhouse Products Ltd.

LIGHTING, EMERGENCY (ACETYLENE)
British Oxygen Co. Ltd.

LIGHTING EQUIPMENT
G.E.C.
Klusterlite Lamps.
Nox Electric Lamp Co. Ltd., The.

LIGHTING SYSTEMS, BATTERY
Batteries Ltd.
C.A.V.-Bosch Ltd.
Chloride Electrical Storage Co. Ltd.
Keepalite.
Morris, John, & Sons Ltd.
Nife Batteries Ltd.
Siebe, Gorman & Co. Ltd.

LIGHTING SYSTEMS (PETROL OR DIESEL DRIVEN)
Air Conditioning Corporation (Jeffreys) Ltd.
Blackstone & Co. Ltd.
Carter & Co. (Nelson) Ltd.
Lister, R. A., & Co. Ltd.
New Pelapone Engine Co. Ltd.
Petters Ltd.
Ruston & Hornsby Ltd.
Sulzer Bros. (London) Ltd.

LINES
Simonis & Bremner.

MANHOLE COVERS
Burn Bros. (London) Ltd.
Crittall Manufacturing Co. Ltd.
Dover Engineering Works Ltd.
Guest, Keen, Baldwins Iron and Steel Co. Ltd.
Haywards Ltd.

MONITORS
Dixon, S., & Son Ltd.
Knowsley Cast Metal Co. Ltd.
Leyland Motors Ltd.
Merryweather & Sons Ltd.

NOZZLES
See Branch Pipes.

OFFICE RECORD SYSTEMS
Morland & Impey Ltd.
Roneo Ltd.
Ryman, H. J. Ltd.

OXYGEN CUTTING EQUIPMENT
British Oxygen Co. Ltd., The.

PAINT (CAMOUFLAGE), Etc.
Carson, Walter, & Sons Ltd.
Drynamels Ltd.
Freeman, J., Sons & Co. Ltd.
Goodlass, Wall & Co. Ltd.
Greyfriars Products Ltd.
Griffiths Bros. & Co. (London) Ltd.
Imperial Chemical Industries Ltd.
Keystone Paint & Varnish Co. Ltd.
Nicholls & Clarke Ltd.
Nobel Chemical Finishes.
Pinchin, Johnson & Co. Ltd.
Silicate Paint Co. Ltd., The.
St. Helens Colour and Varnish Co. Ltd.
United Paint Co. Ltd., The.

PAINT (FIRE RESISTING)
Blundell, Spence & Co. Ltd.
Freeman, Jos., Sons & Co. Ltd.
Goodlass, Wall & Co. Ltd.
Griffiths Bros. & Co. (London) Ltd.
Imperial Chemical Industries Ltd.
Nicholls & Clarke.
Porcella Products Ltd.
Seapak Insulation Co., The.
St. Helens Colour and Varnish Co. Ltd.

PRIMERS (EXHAUST)
British Hose and Appliances Co. Ltd.
Coventry Climax Engines Ltd.
Dennis Bros. Ltd.

PROTECTIVE CLOTHING AND EQUIPMENT
Abbot, Anderson & Abbot Ltd.
Angus, George, & Co. Ltd.
Anti-Gas Ltd.
Barr, N., & Co. Ltd.
Bells Asbestos & Engineering Supplies Ltd.
Chamberlins Ltd.
Currie, Wm., & Co. Ltd.
Dunlop Rubber Co. Ltd.
Great Grimbsy Coal Salt and Tanning Co. Ltd., The.
Ioco Rubber and Waterproofing Co. Ltd.
Johnson & Sons Ltd.
L. & G. Fire Appliance Co. Ltd.
Mackean, Edward, & Co. Ltd.

PROTECTIVE CLOTHING AND EQUIPMENT—*continued.*
Maw, S., Son & Sons Ltd.
Merryweather & Sons Ltd.
National Fire Protection Co. Ltd., The.
North British Rubber Co. Ltd.
Roberts, McLean & Co. Ltd.
Seiker, James.
Siebe, Gorman & Co. Ltd.
Walters, H. E.
Yuille, John.

PUBLIC ADDRESS SYSTEMS
Fountain, Guy R. Ltd.
Microphone Equipment Ltd.
Public Address Equipment Co. Ltd.

PUMP TRAILERS
Brockhouse, J., & Co. Ltd.

PUMPS (APPLIANCES)
Dennis Bros. Ltd.
Foamite Ltd.
Kerr, John, & Co. (M/cr.) Ltd.
Leyland Motors Ltd.
Morris, John, & Sons Ltd.
Morris, John (Firesnow) Ltd.
Pyrene Co. Ltd., The.
Scammell Lorries Ltd.
Sigmund Pumps (Great Britain) Ltd.
Simonis & Bremner.
Sulzer Bros. (London) Ltd.

PUMPS (CENTRIFUGAL)
Beresford, James, & Son Ltd.
Blaw-Knox Ltd.
Dennis Bros. Ltd.
Pyrene Co. Ltd., The.
Sulzer Bros. (London) Ltd.

PUMPS (FIRST AID)
Conjoint Constructions Ltd.
Scammell Lorries Ltd.
Winn, Charles, & Co. Ltd.

PUMPS (HAND)
Angus, George, & Co. Ltd.
Dennis Bros. Ltd.
Dixon, S. & Son Ltd.
Foamite Ltd.
French, W. T., & Son Ltd.
Hill, H. H. Ltd.
Kerr, John, & Co. (M/cr.) Ltd.
Morris, John, & Sons Ltd.
Morris, John (Firesnow) Ltd.
National Fire Protection Co. Ltd., The.
Pyrene Co. Ltd., The.
Siebe, Gorman & Co., Ltd.

PUMPS (HAND) *continued.*
Simonis & Bremner.
South Wales (Fire Protection) Engineers Ltd., The.
Waldron, The Philip B., Co. (D.E.).

PUMPS (PORTABLE)
Blaw-Knox, Ltd.
Dennis Bros. Ltd.
Johnson, C. H., & Sons Ltd.
Mellor, Bromley & Co. Ltd.
Morris, John, & Sons Ltd.
Pyrene Co. Ltd., The.
Sigmund Pumps (Great Britain) Ltd.

PUMPS (RECIPROCATING)
Merryweather & Sons Ltd.

PUMPS (TRAILERS)
Beresford, James, & Son Ltd.
Blackstone & Co. Ltd.
Coventry Climax Engines, Ltd.
Dennis Bros. Ltd.
Gilbert, Gilkes & Gordon Ltd.
Gwynn's Pumps Ltd.
Kerr, John, & Co. (M/cr.) Ltd.
Merryweather & Sons Ltd.
Morris, John, & Sons Ltd.
Morris, John (Firesnow) Ltd.
National Fire Protection Co. Ltd., The.
Pulsometer Engineering Co. Ltd.
Pyrene Co. Ltd., The.
Scammell Lorries Ltd.
Siemens, Schuckert (Great Britain) Ltd.
Sigmund Pumps (Great Britain) Ltd.
Simonis & Bremner.
Sulzer Bros. (London) Ltd.

RACKS AND SHELVING
Chatwood Safe Co. Ltd., The.
Constructors Ltd.

REINFORCEMENT FOR SHELTERS
Adamite Co. Ltd.
Air Conditioning Corporation (Jeffreys) Ltd.
Chatwood Safe Co. Ltd., The.
Huntley & Sparks Ltd.
Indented Bar and Concrete Engineering Co. Ltd.
Isteg Steel Products Ltd.
Johnsons Reinforced Concrete Engineering Co. Ltd.
McNeill, F., & Co. Ltd.
Mesh Steel.
Mills Scaffold Co. Ltd.
Newtonite Ltd.

REINFORCEMENT FOR SHELTERS *continued*
Pressure Piling Co. (Patent) Ltd.
Rom River Co. Ltd.
Tann, John, Ltd.
Trussed Concrete Steel Co. Ltd., The
Twisted Reinforcement Ltd.
Universal Floors Ltd.

REPAIR OUTFITS (HOSE)
Morris, John, & Sons Ltd.

RESPIRATOR PARTS
S. & D. Rivet Co.

RESPIRATORS
See Breathing Apparatus.

RESUSCITATING APPARATUS
Roberts, McLean & Co. Ltd.
Siebe, Gorman & Co. Ltd.
Sparklets Ltd.

SAFETY DEVICES
Kerr, John, & Co. (M/cr.) Ltd.
Pyrene Co. Ltd., The.
Siebe, Gorman & Co. Ltd.

SAFETY DEVICES (SHELTERS)
Constructors, Ltd.
Mellor, Bromley & Co. Ltd.
Sutcliffe, Speakman & Co. Ltd.
Wallach Bros. Ltd.

SAND CONTAINERS
W. P. Butterfield Ltd.

SANDBAGS
Birmingham Bag Co., The.
Black, W. G., Ltd.
Lewis, Brooks & Co. Ltd.
London Sack & Bag Co.
Malcolm, Ogilvie & Co. Ltd.
Martin, J. W., & Co.
Smith, John, & Co. (London, E.) Ltd.
Thames Sack & Bag Co. Ltd.
Willesden Paper and Canvas Works Ltd.

SANITATION
Austral Cabinet Co. Ltd.
Bolding, John, & Son Ltd.
Elsan Manufacturing Co.
Elt, George.
Jeyes' Fluid.
Stirling Manufacturing Co. Ltd., The.
Transport Engineering Ltd.
Wackett Bros. Ltd.

SEARCHLIGHTS
Francis, T., & Sons

SHELTER LININGS
Lloyd Boards Ltd.
Lock Sheet Lining Co.

SIRENS
Associated Fire Alarms Ltd.
Beattie, S. N., & Co. Ltd.
Carter & Co. (Nelson) Ltd.
Chalk & Harris Ltd.
Francis, T., & Sons.
Gent & Co. Ltd.
Hunt & Mitton Ltd.
Klaxon Ltd.
Newman, Hender & Co. Ltd.
Pulsometer Engineering Co. Ltd.

SPRINKLER SYSTEMS
Automatic Sprinkler Co. Ltd., The
Clarke & Vigilant Sprinklers Ltd.
Independent Sprinklers Ltd.
Mather & Platt Ltd.
National Fire Protection Co. Ltd., The.

STANDPIPES
Angus, George, & Co. Ltd.
British Hose and Appliances Co. Ltd.
Dixon, S., & Son Ltd.
L. & G. Fire Appliance Co. Ltd.
Merryweather & Sons Ltd.

STEEL ARCHES
Appleby Frodingham Steel Co. Ltd., The.
Cargo Fleet Iron Co. Ltd., The.
Colvilles Ltd.
Consett Iron Co. Ltd., The.
Cordes (Dos Works) Ltd.
Darlington Rolling Mills Co. Ltd.
Dorman, Long & Co. Ltd.
Glencairn Metals Ltd., The.
Guest, Keen, Baldwins Iron & Steel Co. Ltd.
Johnson's Iron and Steel Co. Ltd.
Lanarkshire Steel Co. Ltd.
Lancashire Steel Corporation Ltd., The.
Monks, Hall & Co. Ltd.
Park Gate Iron and Steel Co. Ltd., The.
Raine & Co. Ltd.
Shelton Iron, Steel and Coal Co. Ltd., The.
Skinningrove Iron Co. Ltd., The.
Steel Arches Ltd.
Tredegar Iron and Coal Co. Ltd.

STRAINERS
Dixon, S., & Son Ltd.
Kerr, John, & Co. (M/cr.) Ltd.
Ravenhose Ltd.

STRETCHERS
Kingfisher Ltd.
Maw, S., Son & Sons Ltd.
Morris, John, & Sons Ltd.
Tor Equipment Co. Ltd.

SUNDRIES AND EQUIPMENT
Air Defence Equipment Service.
Beattie, S. N., & Co. Ltd.
Braby, Fredk. & Co. Ltd.
British Hose and Appliances Co. Ltd.
Clark, Hunt & Co. Ltd.
Dennis Bros. Ltd.
Foamite Ltd.
Gibbons, J., Ltd.
Hardware Products Ltd.
Hendry, James, Ltd.
Kerr, John, & Co. (M/cr.) Ltd.
Knowsley Cast Metal Co. Ltd.
Koneragas Ltd.
L. & G. Fire Appliance Co. Ltd.
Merryweather & Sons Ltd.
Morris, John, & Sons Ltd.
Morris, John (Firesnow) Ltd.
National Fire Protection Co. Ltd., The.
Nicholls & Clarke Ltd.
Nissen Buildings Ltd.
Pyrene Co. Ltd., The.
Ravenhose Ltd.
Rays Models Ltd.
Reddaway, F., & Co. Ltd.
Safety Automatic Fire Escapes Ltd.
Siebe, Gorman & Co. Ltd.
Simonis & Bremner.
Solent Engineering Co. Ltd.
South Wales (Fire Protection) Engineers Ltd., The.
Sutcliffe, Speakman & Co. Ltd.
Taylor, John, Dunford & Co. Ltd.
Universal Air Defence Services.
Wallach Bros. Ltd.
Winn, Charles, & Co. Ltd.
Woodhouse Products Ltd.

TAPE (GAS SEALING)
A.G.P., Co. Ltd., The.
Durex Abrasives Ltd.
Winn & Coales Ltd.

TELEPHONE SYSTEMS (INTERNAL)
Automatic Telephone and Electric Co. Ltd.

TELEPHONES (ESCAPE)
Francis, T., & Sons.

TENDERS
Dennis Bros., Ltd.
Ford Motor Co. Ltd.
Kerr, John, & Co. (M/cr.) Ltd.
Morris, John, & Sons Ltd.
Morris, John (Firesnow) Ltd.
National Fire Protection Co. Ltd., The.
Simonis & Bremner.
Vauxhall Motors Ltd.

TESTING OUTFITS FOR MAINS AND HYDRANTS
Morris, C. Vernon.

TIES—A.F.S.
Basa-Weave Ltd.

TRENCH REVETTING
Ellis, John, & Sons Ltd.
Trianco Ltd.

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Dunlop Rubber Co. Ltd.
North British Rubber Co. Ltd., The.

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Schneiders, S., & Sons.
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Pyrene Co. Ltd., The.
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Greenwood's Ventilating Co. Ltd.

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Stenor Ltd.

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Braby, Fredk., & Co. Ltd.
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Greenwood's Ventilating Co. Ltd.
Haywards Ltd.
Hope, Henry, & Sons Ltd.
Williams & Williams Ltd.

APPENDIX VII

CAMOUFLAGE PAINT SURFACES CHART

Issued by The Camouflage Committee of the National Federation of Associated Paint, Colour and Varnish Manufacturers of the United Kingdom and reproduced by their permission.

CAMOUFLAGE PAINT SURFACES CHART

This Surfaces Chart is intended to be a guide, and only a guide, to those who are called upon to decide which of three distinct types of Camouflage Paint is likely to be the most suitable for application to some particular structure.

In some of the sections, all three types are listed, in some two, and in two cases only there is but one type of paint listed. The absence of any reference to it in the appropriate section of the Surfaces Chart, means that that particular paint type should not be used; on the other hand the sequence in which multiple references are made implies no order of merit and no discrimination is intended or should be made in this sense.

So many factors relating to such things as the circumstances of application and the precise nature and condition of the surfaces to be painted, enter into the performance of a paint, that the final selection of the paint type to be used should be made "on the job," and in making this decision the advice of "approved" manufacturers and suppliers of Camouflage Paint should be sought.

The figures of approximate coverage capacity are given only as a guide. The quantity used will vary with the character, condition and previous treatment of the surfaces to be covered, the skill of the decorator, weather conditions and other factors, the effect of which cannot be accurately determined on a general basis.

This Chart does not apply to roads, macadam or grass.

On Unpainted Surface of	Use	No. of Coats	Coverage (per coat)
ASBESTOS SHEETING—NEW	OIL-BOUND WATER PAINT OR BITUMINOUS EMULSION PAINT		
	Oil-bound Water Paint used at the correct consistency (*i.e.*, slightly thinner than on other surfaces owing to the porosity of Asbestos Sheeting).	2	Gritty . 60–80 sq. yd. per cwt. Non-gritty 150–175 " " " "
	Bituminous Emulsion Paint	2	Gritty . 60–80 " " " " Non-gritty 150–175 " " " "

On Unpainted Surface of	Use	No. of Coats	Coverage (per coat)	
ASBESTOS SHEETING, ETC.	BITUMINOUS EMULSION PAINT, OIL-BOUND WATER PAINT or FLAT OIL PAINT (provided the surface is neutral).			
	Bituminous Emulsion Paint	2	Gritty	60-80 sq. yd. per cwt.
			Non-gritty	150-175 " " " "
	Oil-bound Water Paint	2	Gritty	60-80 " " " "
			Non-gritty	150-175 " " " "
	Flat Oil Paint	1 Primer plus 1 coat of paint	Gritty	10-15 sq. yd. per gall.
	Because of the abnormal absorption of this surface it is recommended that up to 25 per cent. by volume Boiled Oil be added to the first coat of Flat Oil Paint. In extreme cases it may be necessary to use a specially formulated primer. In these cases apply to the manufacturer supplying the paint.		Non-gritty	15-20 " " " "
GLASS LIGHTS	FLAT OIL PAINT, BITUMINOUS EMULSION PAINT or OIL-BOUND WATER PAINT			
	Flat Oil Paint	1	Gritty	15-18 sq. yd. per gal.
			Non-gritty	55-60 " " " "
	Bituminous Emulsion Paint	1	Gritty	150-175 sq. yd. per cwt.
			Non-gritty	150-200 " " " "
	Oil-bound Water Paint	1	Gritty	150-175 " " " "
			Non-gritty	150-200 " " " "
BRICK WORK	OIL-BOUND WATER PAINT, BITUMINOUS EMULSION PAINT or FLAT OIL PAINT. Whether one or two coats are required depends on absorption. Probably two coats will be necessary for oil paint and one for Oil-bound Water Paint or Bituminous Emulsion Paint. In the case of a very absorbent surface, two coats will certainly be necessary in all cases.			
	Oil-bound Water Paint	1 or 2 coats as required	Gritty	125-150 sq. yd. per cwt.
			Non-gritty	300-350 " " " "
	Bituminous Emulsion Paint	1 or 2 coats as required	Gritty	125-150 " " " "
			Non-gritty	300-350 " " " "
	Flat Oil Paint	1 or 2 coats as required	Gritty	10-15 sq. yd. per gall.
	It is recommended that up to 25 per cent. by volume Boiled Oil be added to the first coat of Flat Oil Paint, because of the abnormal absorption of this surface. In extreme cases it may be necessary to use a specially formulated Primer. In these cases apply to the manufacturer supplying the paint.		Non-gritty	35-40 " " " "

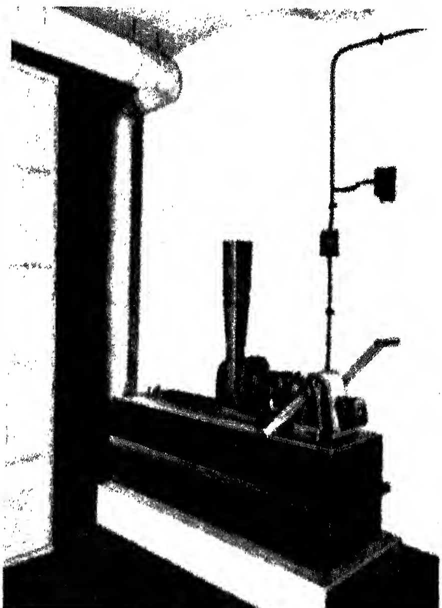
On Unpainted Surface of	Use	No. of Coats	Coverage (per coat)
TILE & SLATE ROOFS	FLAT OIL PAINT, OIL-BOUND WATER PAINT or BITUMINOUS EMULSION PAINT		
	Flat Oil Paint	1 or 2 coats as required	Gritty . 10–15 sq. yd. per gall. Non-gritty 35–40 ,, ,, ,, ,,
	Oil-bound Water Paint	1 or 2 coats as required	Gritty . 125–150 sq. yd. per cwt. Non-gritty 300–350 ,, ,, ,, ,,
	Bituminous Emulsion Paint	1 or 2 coats as required	Gritty . 125–150 ,, ,, ,, ,, Non-gritty 300–350 ,, ,, ,, ,,
CONCRETE & CEMENT—NEW	OIL-BOUND WATER PAINT or BITUMINOUS EMULSION PAINT		
	Oil-bound Water Paint	1 or 2 coats as required	Gritty . 125–150 sq. yd. per cwt. Non-gritty 300–350 ,, ,, ,, ,,
	Bituminous Emulsion Paint	1 or 2 coats as required	Gritty . 125–150 ,, ,, ,, ,, Non-gritty 300–350 ,, ,, ,, ,,
CONCRETE & CEMENT—OLD	BITUMINOUS EMULSION PAINT OIL-BOUND WATER PAINT or FLAT OIL PAINT		
	Bituminous Emulsion Paint	1 or 2 coats as required	Gritty . 125–150 sq. yd. per cwt. Non-gritty 300–350 ,, ,, ,, ,,
	Oil-bound Water Paint	1 or 2 coats as required	Gritty . 125–150 ,, ,, ,, ,, Non-gritty 300–350 ,, ,, ,, ,,
	Flat Oil Paint Because of the abnormal absorption of this surface it is recommended that up to 25 per cent. by volume Boiled Oil be added to the first coat of Flat Oil Paint. In extreme cases it may be necessary to use a specially formulated primer. In these cases apply to the manufacturer supplying the paint.	1 Primer plus 1 coat of paint	Gritty . 15–18 sq. yd. per gall. Non-gritty 55–60 ,, ,, ,, ,,
BITUMEN FELT ROOF & R.P.M. SHEETING	*Bituminous Emulsion Paint*	1 or 2 coats as required	Gritty . 100–150 sq. yd. per cwt. Non-gritty 200–225 ,, ,, ,, ,,
WOOD—BARE	FLAT OIL PAINT or BITUMINOUS EMULSION PAINT		
	Flat Oil Paint	1 or 2 coats as required	Gritty . 10–15 sq. yd. per gall. Non-gritty 40–45 ,, ,, ,, ,,
	Bituminous Emulsion Paint	1 or 2 coats as required	Gritty . 100–150 sq. yd. per cwt. Non-gritty 200–250 ,, ,, ,, ,,
WOOD—CREOSOTED	*Oil-bound Water Paint*	1 or 2 coats as required	Gritty . 150–175 sq. yd. per cwt. Non-gritty 350–400 ,, ,, ,, ,,
GALVANISED IRON NEW (The Galvanised Iron should be degreased before painting.)	OIL-BOUND WATER PAINT or FLAT OIL PAINT		
	Oil-bound Water Paint	1 or 2 coats as required	Gritty . 150–175 sq. yd. per cwt Non-gritty 350–400 ,, , ,, ,,
	Flat Oil Paint (A mordant is required before application.)	Mordant plus 1 coat	Gritty . 15–18 sq. yd. per gall. Non-gritty 55–60 ,, ,, ,, ,,

On Unpainted Surface of	Use	No. of Coats	Coverage (per coat)
GALVANISED IRON (Weathered not less than 6 months.)	FLAT OIL PAINT, OIL-BOUND WATER PAINT or BITUMINOUS EMULSION PAINT		
	Flat Oil Paint	1	Gritty . . 15 18 sq. yd. per gall. Non-gritty 55 60 „ „ „ „
	Oil-bound Water Paint	2 or 3 coats as required	Gritty . 150 175 sq. yd. per cwt. Non-gritty 150 200 „ „ „ „
	Bituminous Emulsion Paint	2	Gritty . 150 175 „ „ „ „ Non-gritty 150 200 „ „ „ „
GALVANISED IRON (Weathered & rusty.)	FLAT OIL PAINT, BITUMINOUS EMULSION PAINT or OIL-BOUND WATER PAINT The most satisfactory treatment for galvanised iron in this condition is to give it a coat of [illegible] per cent of red lead followed by a coat of Flat Oil Paint, Bituminous Emulsion Paint or Oil-bound Water Paint, otherwise the paint will not last very long and rust will continue.		
	Flat Oil Paint	Primer plus 1 coat	Gritty . 15 18 sq. yd. per gall. Non-gritty 55 60 „ „ „ „
	Bituminous Emulsion Paint	Primer plus 1 coat	Gritty . 150 175 sq. yd. per cwt. Non-gritty 150 200 „ „ „ „
	Oil-bound Water Paint	Primer plus 1 coat	Gritty . 150 175 „ „ „ „ Non-gritty 150 200 „ „ „ „
ASPHALT	BITUMINOUS EMULSION PAINT or OIL-BOUND WATER PAINT		
	Bituminous Emulsion Paint	1	Gritty . 100 150 sq. yd. per cwt. Non-gritty 200 225 „ „ „ „
	Oil-bound Water Paint	2	Gritty . 100 150 „ „ „ „ Non-gritty 200 225 „ „ „
ON PAINTED SURFACES IN GOOD CONDITION ACCORDING TO COMPATIBILITY	BITUMINOUS EMULSION PAINT, FLAT OIL PAINT or OIL-BOUND WATER PAINT		
	Bituminous Emulsion Paint	1	Gritty . 150 175 sq. yd. per cwt. Non-gritty 150 200 „ „ „ „
	Flat Oil Paint	1	Gritty . 15 18 sq. yd. per gall. Non-gritty 55 60 „ „ „ „
	Oil-bound Water Paint	1	Gritty . 150 175 sq. yd. per cwt. Non-gritty 150 200 „ „ „ „

INDEX

Carrier

AIR FILTRATION PLANT



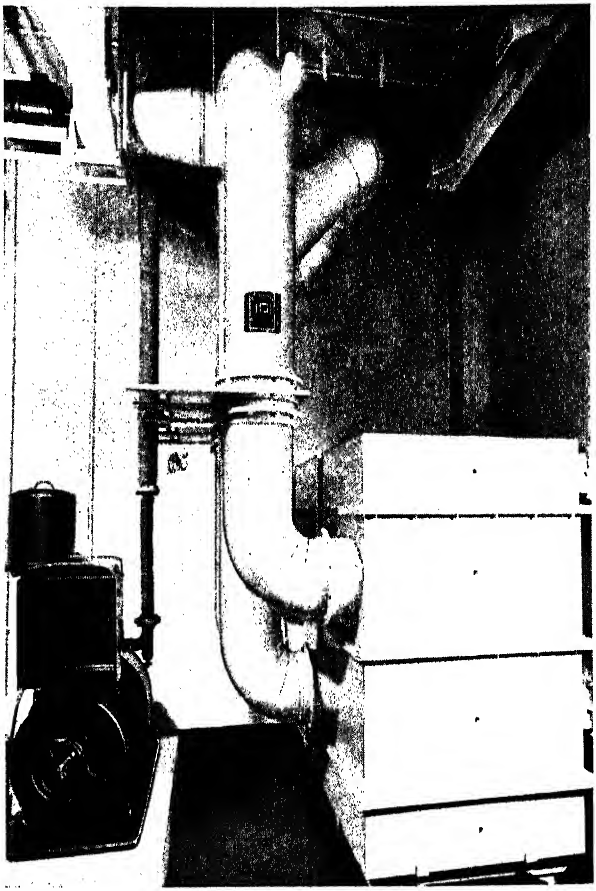
The installation of Carrier Air Filtration Units increases the accommodation of shelters by four or five times. In constructing new shelters the space required is reduced by four-fifths.

One unit provides safe air conditions for 100 persons. Additional units increase the shelter capacity for any number.

Carrier Engineer

24 Buckingham

Carrier Air Filtration installations of any size and output can now be supplied bearing the Home Office Certification Mark.
LICENCES Nos. 1 & 19



The Carrier Air Filtration Plant in a First-Aid and Decontamination Post

The Carrier system allows for vital services to continue during an attack, by maintaining a guaranteed system of protection against poison gases and the elimination of smoke of any kind. Comfortable air conditions are provided for an unlimited period of time. It is already installed in Report Centres, First-Aid Posts, Control Rooms, Buildings of H.M. Government, Colonial Governments, leading Railway Companies, Banks, local authorities and public utilities.

ing Company Ltd
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PORCELLA THE PROVED

We have NEVER claimed:

that timber treated with "PORCELLA" FIREPROOF PAINT would resist the intense heat of an INCENDIARY BOMB but

We have ALWAYS claimed:

that "PORCELLA" Paint would definitely prevent the spread of fire from an Incendiary Bomb.

NOW we are in a position to submit some photographs which definitely prove our claim. These photographs show where a factory was saved from fire by "PORCELLA" FIREPROOF PAINT.

During the last week of September 1940, an ENEMY INCENDIARY BOMB fell through the Glass Skylight of a Modern Factory, and landed on a wooden mezzanine floor, which was constructed of ¾" ordinary deal boarding on 8" × 3" beams. This structure was painted with "PORCELLA" Fireproof Paint, both above and below. The bomb burnt right through the floor and fell on to an ordinary wooden truck, and there burnt itself out. This truck was also painted with "PORCELLA" Paint.

This Bomb must have been burning fiercely for some minutes on the wooden floor before it burnt a hole sufficiently large to enable the bomb to drop through on to the truck on the ground floor, but the sparks and heat thrown off during its burning had no effect on the surrounding structure although there was a partition of ordinary wall board construction (also painted with "PORCELLA") within THREE FEET of the burning bomb.

Shewing condition of "PORCELLA" painted wooden floor after Incendiary bomb had burnt its way through.

THE USE OF ASPHALTE MASTICS IN CONNECTION WITH STRUCTURAL A.R.P.

Owing to their particular physical characteristics Asphalte Mastics are suitable both for the protection of structures against moisture penetration, and against the high temperatures produced by incendiary bombs.

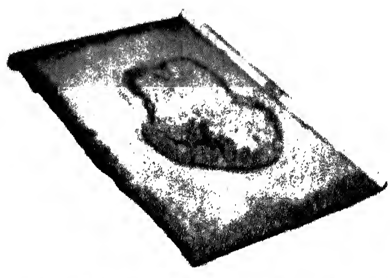
The kind of asphalte used in building is known as mastic asphalte, and differs from other types in that it is a mixture of natural asphalte rock (and or other aggregate) and asphaltic bitumen, in such proportions as to give a plastic and practically voidless mass which can be laid by hand while in a hot, fluid condition.

WATERPROOFING

Asphalte can be used for waterproofing A.R.P. Structures in exactly the same manner as it is used for the tanking of normal basements.
(See Technical Bulletin No. 2 issued by the Council.)

FIRE RESISTANCE

IT HAS NOW BEEN PROVED IN ACTUAL EXPERIENCE, IN NUMEROUS INSTANCES, THAT ASPHALTE ROOFING IS PRACTICALLY UNAFFECTED BY CONTACT WITH BURNING INCENDIARY BOMBS, AND AFFORDS A COMPLETE PROTECTION AGAINST THE SPREAD OF FIRE. *(See attached photograph).*



A typical example of an asphalte surface on which an incendiary bomb had burnt out.

GAS

Contractors represented on the Council are also in a position to supply a special gas-resisting asphalte, which can be decontaminated, and which is appropriate for use as a flooring in those types of structure where anti-gas measures would have to be conducted in the event of aerial attack, such as Decontamination Centres, First-Aid Posts, etc. This material has been approved by the Air Raid Precautions Department of the Home Office, for use in those particular conditions.

TECHNICAL ADVICE

The Natural Asphalte Mine-Owners and Manufacturers Council will be glad to advise (free of charge) on any question connected with the use of asphalte in Air Raid Precautions, or any other war-time purpose.

THE NATURAL ASPHALTE MINE-OWNERS & MANUFACTURERS COUNCIL
91 PETTY FRANCE, WESTMINSTER, S.W.1 Telephone ABBey 1010

Everything for Safety Everywhere"

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To official requirements

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Etc., Etc.

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Designers and manufacturers of breathing apparatus of every description,

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Telegrams: "Siebe, Lamb, London"

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MEMO

A.R.P.

Stent's

Standard 50-person
Shelters

As used by the
Air Ministry

£1 per person housed

Protected entrance

Brochure & drawings

Whitehall
2573

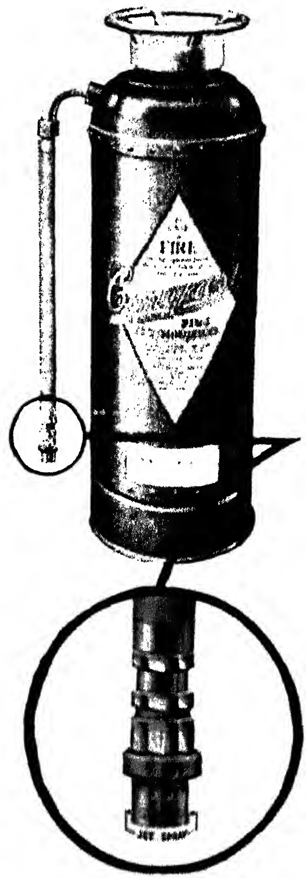
STENT PRECAST CONCRETE LTD., 2 Central Buildings, S.W.1

Fight Incendiary Bombs
SINGLE-HANDED !—

with the

Conquest
TRADE MARK

DUAL PURPOSE FIRE EXTINGUISHER



The above illustration shows the "PYRENE" Dual Purpose Nozzle coupled to the flexible hose of a C.1. "Turnover" Type "CONQUEST" Extinguisher.

You may be called upon to deal with fire bombs at any moment now. With the Dual Purpose "CONQUEST" Extinguisher, you can tackle incendiary bombs and deal with resultant fires single-handed.

The new "PYRENE" Dual Purpose Nozzle projects a fine spray which increases the rate of combustion of the bomb and at the same time cools down the surrounding material. By a slight rotary movement of the knurled nut, a powerful fire-fighting jet is obtained which is effective in extinguishing fires involving freely burning materials, such as wood, cloth, paper, etc.

The "PYRENE" Dual Purpose Nozzle can easily be fitted to all types of "CONQUEST" Extinguishers already in use. Alternatively, the new "CONQUEST" Turnover Type and Break-bottle Type Extinguishers are now obtainable with the Dual Purpose Nozzle already fitted.

Secure this self-contained, combined fire protection now by completing and returning the form below.

THE PYRENE COMPANY LIMITED, Great West Road, Brentford, Middlesex
Telephones: Ealing 3444 (14 lines) *Telegrams: "Pyrene," Brentford*

To: The Pyrene Company Limited Date.......................................

*Please quote for............C.1. "CONQUEST" Dual Purpose Extinguishers.

*We have.........C.1./C.3. type "CONQUEST" Extinguishers. Please quote for conversion. *Strike out wording not required.

Signed ....

Firm ....

Address..

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F.S. Shelters are erected unit by unit in an excavated trench, the earth from which gives regulation 2 ft. covering on top for complete blast and splinter-proof protection.

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THE AIR RAID PROTECTION INSTITUTE

AIMS AND OBJECTS

1. The establishment of a professional body versed in air raid protection measures.
2. To provide a focal point for technical information and discussion on air raid protection.
3. To hold meetings and lectures, and to publish a Journal.
4. To form panels for the consideration of individual problems.
5. To advise and assist authorities, corporations and the general public with regard to the application of air raid protection measures in particular cases.
6. To maintain a register of persons competent to give advice.
7. To grant degrees of professional competency (Fellows and Associate Fellows) to those eligible, and to enrol the support of others as Members.
8. Generally to advance and encourage measures for the protection of the civil population against air raids.

The Institute is non-political.

ACTIVITIES

General Meetings are held each month during the session from October to July inclusive, at which papers are read and discussed. In addition, series of Informal Discussions are held, dealing with various Technical and Administrative Problems.

The Journal of the Institute, which is published bi-monthly throughout the year, is sent to all members. This Journal has already become the authoritative technical publication on A.R.P. practice in this country.

A number of Technical Panels and Committees have been appointed by the Council to investigate and report upon various aspects of A.R.P.

The Library is open for reference by members during office hours.

The A.R.P.I. is the only technical institute engaged solely in the study of air raid protection, and as such is of the greatest value to all who wish to be fully informed in the subject.

Full particulars of qualification for membership are obtainable from

The Secretary,

THE AIR RAID PROTECTION INSTITUTE

2 Millbank House, Wood Street, London, S.W.1

Phone: WHItehall 9227

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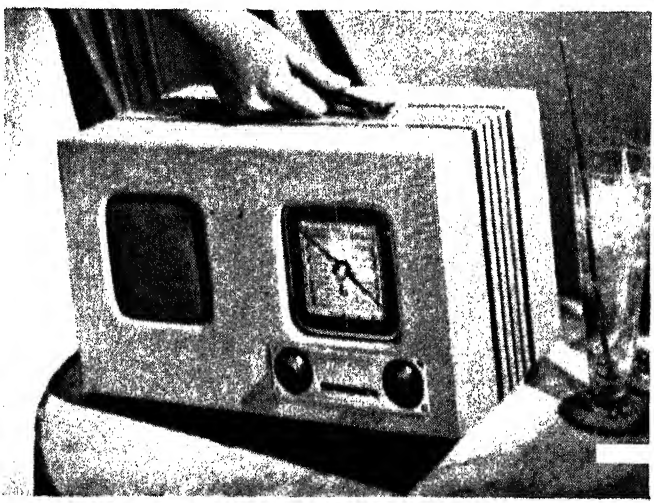

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